MACKENZIE VALLEY PIPELINE INQUIRY

IN THE MATTER OF APPLICATION BY EACH OF
(a) CANADIAN ARCTIC GAS PIPELINE LIMITED FOR A RIGHT-OF-WAY THAT MIGHT BE GRANTED ACROSS CROWN LANDS WITHIN THE YUKON TERRITORY AND THE NORTHWEST TERRITORIES; AND
(b) FOOTHILLS PIPE LINES LTD. FOR A RIGHT-OF-WAY WITHIN THE NORTHWEST TERRITORIES,
FOR THE PURPOSE OF A PROPOSED MACKENZIE VALLEY PIPELINE

and

IN THE MATTER OF THE SOCIAL, ENVIRONMENTAL AND ECONOMIC IMPACT REGIONALLY OF THE CONSTRUCTION, OPERATION AND SUBSEQUENT ABANDONMENT OF THE ABOVE PROPOSED PIPELINE

(Before the Honourable Mr. Justice Berger, Commissioner)

Inuvik, N.W.T.

February 13, 1976

PROCEEDINGS AT INQUIRY

Volume 124

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APPEARANCES:

Mr. Ian G. Scott, Q.C., Mr. Stephen T. Goudge, Mr. Alick Ryder and Mr. Ian Roland	for Mackenzie Valley Pipeline Inquiry;
Mr. Pierre Genest, Q.C., Mr. Jack Marshall, and Mr. Darryl Carter	for Canadian Arctic Gas Pipeline Limited;
Mr. Reginald Gibbs, Q.C., Mr. Alan Hollingworth & Mr. John W. Lutes,	for Foothills Pipe Lines Ltd.;
Mr. Russell Anthony & Pro. Alastair Lucas Mr. Garth Evans	for Canadian Arctic Resources Committee;
Mr. Glen W. Bell and Mr. Gerry Sutton,	for Northwest Territories Indian Brotherhood, and Metis Association of the Northwest Territories;
Mr. John Bayly or Miss Leslie Lane	for Inuit Tapirisat of Canada, and The Committee for Original Peoples Entitlement;
Mr. Ron Veale and Mr. Allen Lueck	for The Council for the Yukon Indians;
Mr. Carson H. Templeton,	for Environment Protection Board;
Mr. David Reesor	for Northwest Territories Association of Municipalities;
Mr. Murray Sigler	for Northwest Territories Chamber of Commerce.
Mr. John Ballem, Q.C.,	for Producer Companys;

I N D E X

Inuvik, N.W.T.

February 13, 1976

(PROCEEDINGS RESUMED PURSUANT TO ADJOURNMENT)

THE COMMISSIONER: Well, we will come to order ladies and gentlemen.

MR. BAYLY: Mr. Commissioner, I have a panel of three witnesses here. From your left, Mr. Jim Shearer, Mr. Allen Milne, and Mr. Peter Lewis. Both Mr. Shearer and Mr. Lewis have given evidence before you in the past and Mr. Milne has been sworn.

ALLEN MILNE, affirmed
CHARLES PETER LEWIS,
JAMES M. SHEARER, resumed:

DIRECT EXAMINATION BY MR. BAYLY:

Q I'll just go over his curriculum vitae which is found at the back of his evidence. Mr. Milne, I understand you received your Bachelor of Applied Science in 1950 in Engineering Physics at the University of Toronto, is that correct sir?

WITNESS MILNE: Yes, that's correct.

Q And that you worked from 1950 to 1955 for the National Research Council of Canada?

A Yes.

Q And that you attended McGill University and received a Master of Science Degree in Physics?

A That is correct.

Q That you followed this by employment with the Defense Research Board of Canada at the Defense Research Establishment of the Pacific in

1955?

A Yes, that's true.

Q That your work there was involved with acoustics research underwater?

A That's true.

Q That you have Arctic experience which includes a number of expeditions led into the Arctic, numbering approximately twenty?

A Yes, that's true.

Q And that you're a Fellow of the Arctic Institute of North America and until November, 1973, you headed the Arctic acoustic group?

A Yes. That's right.

Q And that you're now working with the Department of the Environment as head of the Arctic marine group?

A Yes.

Q And that you were the project manager of the Beaufort Sea project about which we have heard something at this Inquiry?

A Yes.

MR. BAYLY: Mr. Commissioner, we'll begin with the evidence of Mr. Shearer. The only change from the format as is found in the prepared evidence that's before you, is I have requested that Mr. Milne give you a short review of the Beaufort Sea project as he is the manager of it, so that you'll know what its terms of reference and its studies involved.

WITNESS SHEARER: This is a panel presenting essentially the physical environment

properties of the Beaufort Sea. A background discussion of the physical properties and features of the Beaufort Sea will be given. The basis for presenting this information at this time, is that it is felt that much of the basis for petroleum industry's activity in the Mackenzie Delta, is the potential of the sedimentary basin underlying the continental shelf of the Beaufort Sea.

The panel will deal mainly with physical features and processes encountered in the Beaufort Sea, consisting of:

The near surface geology and bottom of the sea and its features specifically related to Beaufort Sea including offshore pingos, sea bottom permafrost and sea bottom scouring, entitled "Bottom Features of the Beaufort Sea", given by myself.

The coastal zone where the transition between the land areas and the Beaufort Sea take place given by Peter Lewis entitled "Physical Aspects of the Beaufort Sea Coast".

Allen Milne will be presenting "Aspects of Climate and Oceanographic Properties of the Beaufort Sea", specifically, those related to harsh weather conditions, the nature of ice movements and timing of breakup and will be discussed in his presentation of "Preliminary Environmental Assessment of Offshore Drilling for Oil in the Beaufort Sea".

All three presentations will deal with these topics in the context of offshore oil exploration and possible future production.

The Beaufort Sea is commonly considered that area of the Arctic Ocean which borders the land masses from Point Barrow, Alaska to the Arctic Islands in Canada and runs the great circle route directly from Point Barrow to Prince Patrick. I was wondering if we could have the lights --

The light color on the slide is the Continental Shelf area of the Beaufort Sea we'll be dealing with in more detail. Can we have the next one Lorraine?

In the southern Beaufort Sea, off the Mackenzie Delta, the seasonal variation in temperature and sediment load is most severe because of the contrast in Mackenzie River runoff from winter to summer. The river runoff is much higher in the summer, containing a much larger sediment load than in the wintertime. ERTS satellite photographs of the western Canadian Arctic Continental Shelf from Herschel Island to just east of Kugmallit Bay show a northeast trend along the edge of the Tuk Peninsula for Mackenzie River runoff.

This easterly moving longshore current is predominant throughout the year and is somewhat more pronounced in the summertime when the Mackenzie outflow is higher. The Coriolis force associated with this higher volume outflow is thought to be one of the major influences determining this particular direction. Because of the law of conservation of momen-

tum, any major movement northwards on the earth's surface will veer towards the east in the northern hemisphere.

MR. BAYLY: I wonder if you could illustrated that on this slide so that we can see how that works, Mr. Shearer.

A The Mackenzie Delta is right here. Most of the outflow comes out of Shallow Bay. Some of the channels on the east side here and most of the sediment load is pulled to the east and runs along in this direction. It appeared most of it is actually deposited into this particular triangle here. It appears this is the main reason for these contours. Let's take the fifty meter contour. It is very far offshore here and runs very closely to shore. The thirty meter contour runs right into shore here so that the bottom -- the original base of the sedimentation here was flat across the bottom and it is preferrentially filled on this side. We feel that it is preferrentially filled on that side because of the turning towards the east of most of the currents coming out of the Mackenzie.

The presence of this Mackenzie water modifies the ambient marine environment with a warm fresh water layer between 15 and 20 meters thick, extending sometimes far offshore to the shelf edge. Where it touches the bottom in water depths less than 15 - 20 meters, there exists a mean annual temperature on the bottom much warmer (slightly above zero) than at greater depths where the temperatures were found to be below zero (between -1 and -1.5° C) even in the summertime. So we would presume that the mean annual temperature

of the bottom waters at depths greater than 20 meters, would be negative. At depths less than two meters, shorefast ice touches the bottom for eight or nine months of the year, allowing conductive heat transfer to the bottom, thus causing temperatures to be even less than -1.5°C. I might add that the lowest temperature sea water of 35 parts per thousand could go is about -1.8°C.

The presence of continental glaciers over the North American continent some 15 to 30,000 years ago tied up much of the ocean's water, lowering the world-wide sea level some 100 meters. On this particular map here, the 100 meter line would be the furthest -- the one furthest towards the top and right along the shelf edge so that the implication is that that whole area was exposed to low mean annual air temperatures.

The result of such conditions, the exposure of the shelf to low mean annual air temperatures, for 10,000 to 20,000 years, was the formation of a permafrost layer some 200 to 300 meters thick. Upon transgression (sea level rise), when the glaciers melted the sea level's water went back to the sea and the sea level rose again -- submergence of these previously exposed areas -- after submergence of these exposed areas, sorry -- the regime of permafrost growth was altered. Presumably, as the sea transgressed over any given point, a positive temperature existed for a few thousand years, when the water depths were between -2 and -20 meters. This is assuming what's happening

today, happened in the past and that there is a warm water zone at depths between -2 and -20 meters. So, we're sort of extrapolating into the past.

This being the case, degradation and melting of the top of any existing permafrost would have taken place. In other words, we can see a zone of permafrost 200 to 300 meters thick developing in the offshore just the way it develops in the Tuktoyaktuk Peninsula today and when the sea advanced over this, just as you could have, perhaps, the sea coming over Tuktoyaktuk Peninsula now, over a period of thousands of years; when the sea level is between -2 and -20, its temperature was slightly above zero so that there would have been downward melting from the very top of this permafrost.

It is thought that melting of the top down to some 50 to 70 meters below the sea bottom took place during that few thousand years. As the sea level continued to rise, and depths greater than 20 meters occurred over any given point, the advent of below zero temperatures (-0.5 to -1.5) would have reversed the trend and caused renewed downward freezing. I'm sorry, this all sounds very complicated.

This refreezing from the surface downwards implies the existence of frozen ground on the surface. Nevertheless, on many seismic records, the top of the permafrost is still apparently at -50 meters or so, below the sea bottom. Could we have number three? I'll just go up and explain. The seismic record taken from a boat using an airgun sound source and a very sensitive hydrophone to receive the signal that the air gun

sends out through the water. This is the water surface here and this is the bottom and the signal, it's a sound signal that is sent outwards in all directions. It hits the bottom and returns the signal from the bottom and a return signal from various horizons underneath the bottom. Now, this isn't a very good seismic record but what it serves to point out is that over here we feel that we've got a very strong reflector that dies out quite quickly in this direction. We feel that this is representing frozen ground. A colleague of mine working up here, Jim Hunter has done some refraction seismic over this and it is a somewhat similar method of obtaining velocities, seismic velocities within these sediments and he obtained a very high velocity at this depth. A velocity of roughly ten to 12 thousand feet a second which can only be explained in this area, because it's all very soft sediments by frozen ground.

THE COMMISSIONER: I still don't understand this. I thought that the theory was that as the sea covered the exposed ground which had been frozen when the sea level was lower, that it would have thawed and then as you got to a depth -- a greater and greater depth -- you would get refreezing, but it would be at the surface -- not the surface, but the bottom -- and that appears to be some distance beneath the sea bed.

A Right. O.K. I was just getting into -- there seems to be a discrepancy in terms of our model to what we find offshore.

Nevertheless, on many seismic records, the top

of the permafrost is still apparently at -50 meters below the bottom and as you say, you would have expected it to be freezing from the surface down and I would feel that theoretically, there's been enough time to freeze right from the surface back to this lower layer. Two main reasons for this apparent disagreement are that There is a sedimentary change at this level with the overlying very finely grained sediments and because of their small pore spaces, refreezing at these temperatures would not have occurred. This would assume that the original theory of freezing down to -200 to 300 meters that this top layer might not have frozen as well, but we weren't around then, so we don't know. I think in your geotechnical discussions in phase one, you were probably shown that very fine grained sediments -- in very fine grained sediments, you can have a lot of unfrozen pore water at very cold temperatures. So I think if at say -1.5°C, here, if you had a certain very fine clay or silt, it would not freeze.

The second possibility, is that the material is sandy with large pore spaces that became filled with salt water during the couple of thousand years when they were unfrozen, so that you would effectively saturate the sediments with salt water and then of course they wouldn't refreeze because they're the same as the water on the surface.

In some nearshore areas, frozen ground may be found very close to the surface because shoreline retreat is very high and frozen ground has not had enough time to respond to the average positive temp-

eratures in the shallow water zones.

With a change in mean annual temperature on the surface from -10° to -1.5, the new base of the permafrost layer would be much closer to the surface. The reason for this is that the new equilibrium depth for the bottom of the permafrost where the heat loss to the surface from the cold is equal to the heat gain from the center of the earth, would be much shallower when temperatures -- No, I think I made a mistake there. It should be much shallower when the temperatures were -1.5 and not -10.

Offshore permafrost then, figure four, is a relict phenomena formed 20, 000 years ago, with the top being preserved by the presently existing conditions, and the top could be in a frozen or unfrozen state. This is a figure. The red is a figure of where seismic refraction has picked up evidence of frozen ground. The yellow is where it seems to be intermittent and the blue is where it seems to be absent and this is no comment as to how far down below the bottom we find it. Just the fact that it's present or it's not present.

Yes , this particular map was calculated using the front ends of seismic records from Gulf Oil's Offshore Seismic Program and we'll get into later why the Mackenzie Bay area on the lower left side doesn't have any frozen ground.

Not all areas offshore became frozen when exposed above sea level during the last glacial period. As on the Tuktoyaktuk Peninsula now,

large lakes where the ice did not freeze to the bottom in winter have a perennial layer of unfrozen fresh water underneath. Likewise, underneath deep river channels, greater than six feet deep, many of the narrow, deep channels of the Mackenzie Delta, the soils may be unfrozen. With the onset of the sea level rise and replacement of this unfrozen fresh water (this is on the exposed Continental Shelf). I have to say that again. With the onset of the sea level rise and replacement of this unfrozen fresh water in these previously protected deep lakes, by salt water at negative temperatures, a unique feature developed. The formation of subsea pingos,approximately 125 discovered to date is another significant morphological feature occurring after submergence.

This, again is a seismic record with the scales were actually put on incorrectly on that map and where I've got a rough zero line is where the real sea surface was, but this is -- the dark line you see in the middle of the figure is the shape of the bottom and the pimple-like feature we see there is what we call a subsea pingo and in this particular figure, it has very much the profile of pingos, say at the Tuk Peninsula area, etc.; if you notice the scale, the scales aren't equal in the horizontal and vertical directions so that that particular feature is actually a lot flatter than it really looks there.

Note also, the sub-bottom horizons running underneath the pingo. I'll just point

those out. This particular dark line here is a reflector that was picked up by the seismic energy here and sent back to the recorder. This is the bottom and there's enough energy in the airgun to go down into the bottom and pick up this particular horizon. It sort of runs off like this and this particular one here runs straight across the bottom. It's specifically these, the behavior, the orientation of these horizons that we feel that this is a subsea pingo and not some kind of mud lump that you get in other deltas of the world. Not the Mackenzie Delta because a mud lump would have formed by a compaction of sediments from say a number of hundreds of feet down and you would not have a line running right across the bottom like that. You would have everything curved up and you would see that it would look like a plug that had come up from underneath.

Pingos in the subsea mode are formed by the same mechanism as those formed in the subaerial environment, except that they have formed in response to a negative mean annual bottom water temperature of -1.5°C compared to the low mean annual air temperature of about -10°C.

Upon examination of the detailed bathymetric maps, these features are found to exist over much of the continental shelf, but are absent over a broad area northwest of the Mackenzie River Delta. Could we go back to two, please? Great. The small dots you see on the top and righthand side are the locations of subsea pingos. There's quite a few more further to the right, but the slide doesn't go over that

far, further east off the Tuk Peninsula.

The trough observed, somewhat of an aside here. The trough observed in the chart has been called the Mackenzie Canyon and is thought to have been the locale of a large ice tongue which ran out the Mackenzie Delta during the last glaciation. This explains why no offshore permafrost is found here, because the area wasn't exposed to low mean annual air temperatures. In other words, there was a large ice tongue. I'll just go and point that out. The proper name would be Piedmont Ice Tongue which gives Mr. Bayly a kick.

We feel that a large ice tongue came up the Mackenzie Delta and essentially carved a canyon right down here. It's really the ancestor of Mackenzie Bay and it would have been active in this area probably a wet base glacier with temperatures around zero so that no permafrost would have developed in this area. This is the reason for figure four, I think, with blue, mainly in this area. There's a large blue area in here which we haven't really come to any conclusion why there is none over here because if you had a large ice tongue coming down here and lower sea level, the shoreline along this edge over here. This whole area would have been exposed, as the Tuk Peninsula is down and subject to the same features.

Mackenzie Bay and the Beaufort Sea receive sediment mainly from Mackenzie River runoff and from erosion of the shoreline by wave action and melting of ground ice in the summertime. Thickness

of sediments are very high in the Mackenzie Bay with a significant decrease from over 300 feet to 30 feet or less, as one moves further east. Generally, much of the sediment observed (figure six) to the east was deposited in river channels at the time of lower sea level and does not really represent recent deposition of Mackenzie River sediments. I'll just explain this.

This is a contour line of sediment thickness and I have it written as twenty meters here. It's much thicker. It's up to a hundred meters in cases generally in this bay and becomes -- there's a ten meter, another ten meter in here and we feel that during the times of lower sea level the East Channel that takes -- deviates from the main Mackenzie Delta at Tununuk running down here, we feel that it ran out this particular -- in this particular direction, during times of lower sea level and with the shoreline in this area. So that I think a lot of the sediments we picked up here in our very high frequency ecosounding are, in fact, sediments deposited when the sea level is lower in the east -- and they are all East Channel sediments. Nevertheless most -- we feel that most of the sedimentation from the Mackenzie River ends up in Mackenzie Bay and there is sort of exponentially decreasing thickness down to thirty feet and even less than ten feet over. This is a three-- these wide areas are three meter contours so that there is sediment over the whole Beaufort Continental Shelf but it's quite thin. It's five or ten feet thick over most of it, except for these channels and we feel they

may be altered.

So up to now, we've dealt with two particular phenomena which we find on the Beaufort Shelf; Offshore permafrost and offshore pingos. Now, we'll spend some time with the scouring problem.

It's been found in both the Alaskan and Canadian Arctic Continental Shelves that large ice islands and -- O.K., I'll explain these figures, first and then continue the sentence. This is a figure of an ice island around -- aground -- in about fourty feet of water on the west side of Mackenzie Bay. Note the horizontal laminations in the ice. The island is roughly fifty meters across and six meters high above the water line. This is very similar in size to the next figure, which is a pressure ridge, a multi-year pressure ridge. This shows a large chunk of -- oops, excuse me. This is a multi-year pressure ridge, thought to be aground in about eighty feet of water, some fourty miles north of Tuktoyaktuk. It's about seventy meters across and ten meters above the waterline, so it's slightly larger than the ice island you saw before. Note the irregular chunks from which it's composed and both these pieces of ice rise roughly a quarter of their total height above the waterline. So it's one above and three below, is what it seems to be for most of these floating pieces of ice island and pressure ridge.

O.K., I'll begin that sentence again. Large ice islands and pressure ridges

figure seven and eight when frozen into the polar pack, may encounter the bottom -- which is the next figure -- forming trenches or scours, kilometers in length and up to ten meters in relief. This is just a photograph of a small piece of ice with a lot of dirt frozen onto the bottom and I sort of intuitively feel it's from running aground and then the iceberg was melted during the summer and we have pieces of the bottom frozen into the ice floating to the surface where we can see them, although it is possible that this formed at the shore-line and you had spring melting and the stuff came down, froze on the ice and then drifted out. But I don't think so, mainly because of the chunky nature of the ice that this kind of ice doesn't exist that close to shore; although I could certainly be wrong on that.

The water depths to which scouring is significant is defined by the draught of ice fragments floating in the ice pack. The thickest observed pressure ridge, to date was found from a Polaris submarine to be 153 feet below mean sea level. All the ice islands as we saw in figure seven, for example, found in the Canada basin section of the Arctic Ocean and western side of the archipelago come from the Ward Hunt ice shelf on Ellesmere Island. These ice islands have been found to have a maximum draft of about 120 feet.

Just as an exercise, if they're 120 feet thick and one quarter is above water, you would expect that they could touch the bottom at, say,

ninety feet of water -- eighty, ninety feet of water.

Scouring is a cumulative process such that with time, enough scours may exist in any one given area, so that when further scouring occurs, an older scour is overrun. This phenomena is called saturation -- the saturation level and is expressed generally as the largest average number of scours observed per kilometer -- around fifteen to twenty. Yes, this is a slide which I think I mentioned last time on cross-examination two weeks ago when I was questioned about this, and it's particularly the top -- the graph is just the number of scours found at given depth. I'll just point it out, it looks difficult to read.

This is zero, ten, twenty scours. Zero, twentyfive feet, fifty feet, seventyfive feet, a hundred feet. This would be water depth. So, when we run our sidescan equipment over these particular depths, and I'll be getting into that in a minute; at these various water depths, we see this number of scours per kilometer. At first sight, you would say "O.K. we have most of our scouring happening at fifty to one hundred feet,"but I don't think this is the case. I think it's in slightly shallower water and that in deeper water you reach the saturation level after a number of years, so that this represents total-- essentially total scours and after twenty and twentytwo, everytime you add another one, you're erasing one before, so you that you never get higher than that particular number. But, if you could actually record

every scour, for every time ice hit bottom in a particular depth, I think between fifty and seventyfive, would be away much higher.

Yes. The time taken to reach this saturation level is unknown, but it is presumed to be much less in shallower water. Most scouring is thought to take place in water depths of ten to thirty meters and with time, gradual accumulation of scours at greater depths will occur and the saturation level will be reached. Beyond 150 feet, it is assumed that not enough time has yet passed for this number to be reached. The paucity in very shallow water of less than twentyfive feet, is thought to be due to a combination of higher sediment infilling and the lack of scouring because of shorefast ice. And I think that most scouring occurs in the wintertime when these pressure ridges and ice islands are frozen into the polar pack and your momentum is just tremendous and so these things are just like little pins sticking out of the bottom of plywood and if you move the plywood, the pins are certainly going to rub into anything you move the plywood over.

Yes, I'm just thinking of the analogy, that one would feel that the pin would break, except if the pin were in very soft sediment, it would probably go through it and not break.

Figure 11 is a side scan record taken in about 20 meters of water where the level of scouring --

THE COMMISSIONER: Excuse me,

Dr. Shearer. You say it would be like a pin to the bottom of a piece of plywood. I know you're just using a rough analogy but I should have thought it would be more like like a keel. I thought the action would be sort of along and not sort of down.

A Oh. O.K. I meant a pin in the plywood being moved sideways rather than being pushed downwards, I'm sorry, yes.

THE COMMISSIONER: Well, I don't know if we're any further ahead.

A No, well, I was trying to make the analogy of, if you have something somewhat ridged sticking through a very massive -- the polar pack is very massive and these things are frozen into it so when the polar pack is blown by wind, if one of the solid pieces of say blue ice from an ice island hits the bottom, it's just -- it has the whole momentum of the polar pack behind it so that it would just sort of move along the bottom and just plow up the bottom sort of.

THE COMMISSIONER: Oh, you mean that the ice island might -- the whole island might be shoved along.

A Yes.

Q OH, I see.

A It's frozen into the polar pack and when it touches the bottom.

Q As the polar pack expands it moves the ice island ahead of it, is that it?

A Well, it could be frozen

into it. They're floating around in the summertime and then they gradually get frozen into the polar pack. In the wintertime when the polar pack moves into twenty to thirty meters of water, it can't get in past the shorefast ice or there is an open lead there. Now, any piece of ice frozen into it -- not necessarily on the edge of it, but just frozen into it and moving with it, as it moves in say the Beaufort gyre, if it comes into contact with the bottom, it will just plow it like a snowplow.

THE COMMISSIONER: Fine.

A Figure eleven is a record taken in about twenty meters of water where the level we feel is, the level of scouring, we feel, is very close to saturation where a fresh scour can be distinguished from an older one. I'll just point that out. The ship moves along this direction and it tows a small fish behind it that is a side looking sonar. It sends out signals below the ship and progressively sideways and picks up signals from the bottom. This doesn't go into the sub-bottom now, as the seismic does, it just picks up the shape of the bottom. So, as you move along, you send out a signal and wherever you have these long linear features here, we feel are scours into the bottom. The dark part of the scours where we have a signal return, the edge of the scour would be facing the ship and you'd have a strong signal return and the light color is where you have a bank facing away from the signal and no signal return. In this particular record, this scour here is very fresh looking. It's got good contrast between light and dark and you can

see the mounds thrown up at the side. So we feel it's very recent and these things -- these mounds haven't subsided or been covered in by -- this is in Mackenzie Bay -- been covered in by recent sediment. Here is a number of older scours which seem to be flat on the bottom and I think they're flat because they've been filled in by sediment for a number of years, just as you would fill in a trough or fill in a river channel. So, we feel this is a very fresh scour although we have no real knowledge of how many years.

The next figure, figure twelve, this is the top of figure twelve -- it's not a very good figure, but they're all -- the scours seem very fresh, although they're presumed to be quite old because the record is located east of Mackenzie Canyon some fourty miles north of Atkinson Point.

Repetitive side scan surveys over the same areas, ranging from shallow to deep waters, should, after a number of years, give an idea of the time frame involved in the addition of scours. In other words, the only way to find out how often this happens is to go back over the exact same area and repeat the surveys and see if there's any additions from one year to the next.

Figure 13 and 14 -- we'll just leave it on 13 for a while -- show the aerial distribution of scour frequencies and maximum scour depth for much of the offshore area of the Beaufort Sea. These figures were constructed from original Canadian Geological Survey data by the Arctic Petroleum Operators

Association. Figure 13, the one we have here, shows saturation scouring has occurred to depths of fourty to fifty meters or 150 feet. The very dark color means that most of the bottom is just covered with scours like the two figures you saw before.

Figure 14 demonstrates that no matter what age, most scours dig into the bottom to ten feet or less. I'll just point that out. Most of the area -- it's sort of limited, the coverage we've got here -- but most of the area is -- the lighter blue colors which would imply that these scours don't dig into the bottom to any ~~extreme~~ extent. I think 95 percent of them are ten feet or less.

O.K., figure 15 would just show that -- what we mean by ten feet or less. This is an ecosounding record over an area in Mackenzie Bay running from about fifty feety of water out to 150 feet and the irregularity in the bottom, we feel, is due to scouring and we don't see any relief there; any scour that's greater than ten feet. In fact, most of them are between five and eight. I feel that the shape of the scours in deeper water is partly due to age. They're older, they've been filled in with sediments so they've got a wider shape and I think it's partly due to ice. You need a larger block of ice to scour in deeper water, therefore, your scours are apparently larger. Or, your scours are really larger.

O.K. I feel that in terms of exploration drilling in the offshore, the variability of climate and irregularity of moving ice and personal

human error present more of a problem than the scouring, pingos and offshore permafrost, and this facet will be dealt with later by Allen Milne. The permafrost and associated surface hydrate problems that are encountered in exploration drilling on land will likewise exist offshore and may become a significant problem here. The surface weather conditions might provide the one added complicating factor that could push the operation beyond the critical point.

The wellhead is planned to be buried in a silo, below the level of maximum scouring for the given area, so that when completed, it will be out of danger.

Now, depending upon the method of production of oil and gas, a number of problems may exist.

If one assumes that initial processing of either oil and gas must take place on-shore, then the presence of flowlines is the first requisite. As mentioned previously, in evidence presented entitled "A Possible Future Scenario for Petroleum Development", these flowlines must be buried so as to avoid contact with floating ice. Depending upon where the first discoveries are made, subsequent detailed work on the shortest flowline, and perhaps a natural channel to shore, it may be only necessary to bury some parts of the line to ten feet or so, with other sections in water depths greater than 180 feet just laid on the surface.

Could we go back to figure 13,

I guess. I just want to show scouring in these channels. This is the scouring frequency which we saw in the bottom and I showed you before. The old East Channel, which ran out here, the East Channel which we thought ran offshore during a post-glacial -- when the sea level was lower; the East Channel ran out here, well, as a channel running out here means a slight depression so that offshore now bathymetrically there's sort of a -- well it's the shape of a river channel only it's covered by the sea and we see evidence here that the amount of scouring has decreased significantly in the area of this channel. You would expect that floating ice would come along here and if it cleared the ridge to get into the channel, it wouldn't touch the bottom, because the channel's deeper. So that depending upon where discoveries are made offshore, one might be able to use these channels as a way to get in and not have to bury the lines so deeply.

This potential burial leads to the next problem of offshore permafrost and its potential destruction from a hot flowline.

The flowlines must be kept hot so that "slug flow" and higher viscosity does not form in the gas and oil respectively.

Again, depending upon where discoveries are made, and after detailed surveying of the most likely route to shore, it may be found that very little frozen ground exists along the chosen route. If, in fact, it was found that burial must take place in a zone where frozen ground exists, it would be

necessary to insulate the hot wire flowline from this by having a refrigeration coil on the outside.

If frozen ground can be avoided, by an offshore, hot flowline, what actual effect will this hot line have on unfrozen sediments? Likewise, if it's possible to process the gas subsea in deeper water, say -180 feet -- in other words the gas would -- we could process it and chill it -- what effect of the gas line on these unfrozen yet below zero temperature sediments would occur? I feel that this is a pretty unlikely thing to happen, is processing at subsea in 180 feet of water, although they're doing it in -- well no, they're not actually processing it in the Gulf of Mexico. They just got subsea hook-ups.

An alternative to shipping oil to the south by pipeline down the Mackenzie to use tankers and/or submarines. This is thought to be quite difficult because of the severe weather conditions in the area. Nevertheless, if this mode of transportation is chosen, it would necessitate more detailed bathymetric surveys to locate all the subsea pingos that exist offshore. The "Manhattan" on its voyage through the Beaufort Sea, missed, by one nautical mile, totally by accident, a subsea pingo on which it would have run aground. This was found to be the case after two years of somewhat intensive sounding surveys. But even so, some of the line spacing for these, during this detailed survey was wide enough to miss completely one of these bottom features. At this point, one does not know how many have been missed, nor in fact if any have.

That concludes the presentation and the basis for the information presented here was research carried out under the auspices of the Geological Survey of Canada.

MR GOUDGE: I wonder, sir if we might break for coffee. I think Dr. Lewis has some slides to set up that might be helpful.

THE COMMISSIONER: Fine.

(PROCEEDINGS ADJOURNED AT 11 A.M.)

(PROCEEDINGS RESUMED AT 11:20 A.M.)

MR. BAYLY: Mr. Commissioner I propose now to ask Mr. Lewis to go through his evidence before the Commission and I'd like to suggest when we come to the cross-examination, because of a meeting that Mr. Milne has in Yellowknife tomorrow that counsel consider the possibilty of cross-examining the witnesses in turn so that Mr. Milne may possibly be able to catch his airplane tonight,

MR. COMMISSIONER: Well I'm sure that's no problem.

MR. BAYLY:

Q Mr. Lewis, if we could turn to your evidence please, and you could give that to the Commission.

WITNESS LEWIS: Yes. I'll be talking today on the physical aspects of the Beaufort Sea coast, and in particular those aspects which might be important in any plan to develop hydrocarbon resources offshore. In the development I include both constructional and operational requirements, for example pipelines coming ashore, harbour development, staging facilities and the coarse aggregate mining necessary for their construction, and because any pipeline from offshore will probably need to move some oil or at least some liquids, oil and/or water as well as gas, the consequences of an oil spill from a broken pipeline is also relevent.

For the purposes of my discussion this morning I have defined the coastal zone as the area between the highest storm tideline on land which is about ten feet above mean sea level and the thirty foot water

depth, which is generally assumed by most people who study coasts to be the seaward limit of bottom material movement by waves.

I think the effects of development in the coastal zone are of particular importance because it contains large bird and fish populations and because it is part of the Beaufort Sea coast-- of the Beaufort Sea, excuse me, the most used by man at the present time.

If I could have the first slide please. This map will be coming up several times during my discussion, but for the moment I just intended to show the area that I'm going to talk about. It's the length of coast with which I am personally familiar and it extends from the Alaskan border which is basically the black A on the left hand side of the slide, through to Cape Dalhousie which is the K on the right hand side of the slide. So I'll be considering coastal features along at the entire area from A to K; and the topics I intend to cover include the effects of an Arctic environment on the coast and on coastal processes, near shore water circulation, storm surges, coastal land forms and materials and the coastal stability, all in the context of the influence they should have on the type, extent and location of facilities associated with hydrocarbon resource development.

So first to the effects of an Arctic environment on coastal processes. I think it's important to realize that the Beaufort Sea is in some senses not true Arctic in nature . The open water season, particularily where the influence of the Mackenzie River

is felt, is very long by Arctic standards. So for three to four months a year there can be tens or even hundreds of miles of open water on which wind can generate waves, to cut back the coast. But on the other hand the response of the coastal materials to the attack by these waves is in most respects true Arctic in nature, and I mean that in the sense that frozen ground plays a very important role in the coastal zone. Unlike areas such as the Canadian west coast, coastal materials along the Beaufort Sea are unconsolidated. No bedrock is present, but because if this unconsolidated material is permanently frozen and contains considerable amounts of ground ice in many locations, both the nature and rates of coastal change differ considerably from what they might be in a more temperate climatic setting. The net effect of all this is quite complex, because of the long open water season and the unconsolidated nature of the materials, the entire coastline is retreating, however the rate of retreat is controlled to a large extent by the nature, amount and location of ground ice in the sediments. Where the coast is composed of coarse sands and gravels the frozen nature of the materials may slow down wave or ocean, but where large amounts of ground ice are present the retreat will be even more rapid than if the materials were unfrozen in the first place.

From the development point of view, these factors are critical. The facilities which might be built must contend both with an active summer marine environment and with the presence of frozen ground, a situation for which there is no parallel in past hydrocarbon development.

Nearshore water movement next: The patterns of water movement in the coastal zone are quite different from the offshore circulation which will be discussed by Mr. Milne. As you will see however, they are very relevant to the effect an oil spill might have on the coast. Because the Beaufort Sea coast has been conditioned by the relatively rapid erosion and redistribution of the materials of which it is composed, the position and orientation of resultant depositional features like this spit just north of Tuk, can be used to infer the dominant direction of sediment movement and thus the dominant longshore current direction at any location where they are present. In this case, because of the nature of this feature we can tell that sediment is moving down the coast from the left hand side of the slide toward the lower right hand side of the slide, simply by the way the feature has extended itself out from the coast, and that implies in turn that the dominant nearshore currents move in the same direction. Please note I used the term "dominant direction." I don't mean to imply that this is the only direction in which currents thicken flow. That is a function of wind direction for example as well. But it is probable that the dominant directions are those in which oil would move during major sediment transport events, that is to say during summer and fall storms, when low lying areas could be flooded by the sea level rises associated with strong onshore winds and thus would be open to inundation by any oil which was in the water.

Here's our map again. I plotted dominant current directions for the Beaufort Sea coast

on this map as black arrows, which unfortunately probably for most of you it's hard to see the points and therefore the direction, But on the basis of these directions I've divided the coast into segments. Each segment consists of a sediment sink toward which material is being moved and the contributing source area. The segment boundaries are indicated by the yellow lines on the map and each segment-- there are eleven in total is labeled by the black letters on yellow backgrounds. So we have along the Beaufort Sea coast a number of segments, within which sediment moves.

MR. GOUDGE: Mr. Lewis I can't see the arrows and I don't know whether others can either though. I wonder if you'd mind going to the screen and could you just point it out.

WITNESS MILNE: My pencil's moving in the direction of the arrows.

MR. GOUDGE: I see.

WITNESS MILNE: The general transport comes up through here and then here down to there, back into here in the sink and then the sink, transport there and transport there. I think the main feature is this movement up over here.

WITNESS LEWIS: I think the important point I want to make here is not what direction the arrows go. It's that the coast is composed of a number of segments and that particularly during storm events, oil reaching the nearshore zone will tend to stay within the segment where it first comes into shore, rather than to move between segments and all along the coast and that when it does come into a segment that it will tend to move toward the sediment sink of that segment.

It might appear attractive then to locate shore installations having a high potential for oil spillage in the sink areas because if you spilled the oil it would perhaps tend to stay there. Unfortunately sediment also likes to move into the sink areas and that means that they are usually very shallow and they contain major spits and lagoons that are favorite locations for fish and shore bird populations.

I've mentioned sea level rises already, associated with strong onshore winds during summer and fall storms. These rises are sometimes called storm surges. Based on an examination of tide gauge records at Tuk, Dr. R.F. Henry of Ocean and Aquatic Affairs, D.OE. identified 22 surges which caused water level rises of more than 3 feet in between 1962 and 1973, including two of which caused rises of more than 6 feet, that is a rise of more than 6 feet above mean sea level. A September 1970 storm, for which no tide gauge data is available may have caused a rise of as much as 10 feet at Tuk. These surges are of importance for several reasons. First they occur during storms and they are associated with waves and these waves cause much of the erosion and longshore sediment movement which occurs along the Beaufort Sea coast. I'll discuss this topic in somewhat more detail later. And second, they lead to the inundation of low lying coastal areas by sea water, the water which might contain oil in the event of a spill.

This slide is a view of a major spit at Kay Point. It's about three miles long and its crest is about three feet above normal mean sea level.

This picture was taken in June of 1975 . The next slide is identical to this slide. It's taken with the same camera, from the same position during a minor storm surge along the Beaufort Sea coast. So here we have normal and during a small storm surge, same picture. So as you can see they can be inundated by a surge and you can see the waves.

Perhaps of even more importance because they are of greater area extent than these spits bars and beaches are the low lying delta areas of the Beaufort Sea coast, which are all major wild fowl nesting and staging areas and which also could be inundated by a storm surge and by oil or other pollutants contained in the water. Driftwood lines on the Mackenzie Delta indicate that much of the outer delta could be inundated by an extreme surge to as far south as the lower green line on this slide which is the one with the figure 3 right above Mackenzie Delta. This is a line which represents the location where the channel banks, that is the highest parts of the delta plain are lower than three meters. North of that line the height of the channel banks is less than three meters or ten feet approximately. South of that line greater than ten feet.

The area then which is subject to storm surge inundation on the delta is almost 1500 square miles, which if it were square it would have sides about 40 miles long. So you've got a 40 mile by 40 mile area basically, which is subject to inundation by storm surges, and about 20 percent of that 1500 square miles is covered by shallow lakes in which pollutants could be

dropped and of this lake area about 30 percent or 86 square miles is connected by channels which eventually reach the sea.

THE COMMISSIONER: You're speaking still of the lower delta, north of the drift-wood line ?

A Yes I am . So into this latter type of lake I've talked about that's a lake which is connected by channels-- the pollutants could be carried into this type of lake even by surges which were not high enough to flood the delta surface. So we have a very large area which is subject to inundation by storm surges. Now exactly how far up the delta sea water might penetrate during a surge is dependent upon the influence of river flow as well as upon surge flooding, and to my knowledge, no research has been undertaken into water circulation patterns over flooded areas of the delta. But Dr. Henry's storm surge studies suggest the possibility that sea water and associated pollutants might be drawn in on the Shallow Bay side and river water diverted out East Channel. So although you can flood an area-- the area I talked about, we don't know exactly what part of that flooded area is covered by river water and what part is covered by sea water. That's the point I'm trying to make there, and if we assume that the oil is associated with sea water, that's an important question.

Let's move now to a discussion of the major land form types found along the Beaufort Sea coast and of the importance of their nature to development. To within each of the coastal segments I have

identified, one or more of the following types of land forms dominate the coast. First steep cliffs, often with large amounts of ground ice in them and fronted by narrow beaches; second, thermokarst lakes breached by coastal erosion; third, spits and barriers up to eight miles in length and several hundred yards wide and lastly, river deltas, particularly that of the Mackenzie which is one of the largest deltas in the world.

So first the coastal cliffs. Of these four types of landform coastal cliffs occupy the largest portion of the shoreline in all coastal segments, except for the modern Mackenzie Delta which is segment E there and the eastern end of the Tuk peninsula which sections J and K.

High and steep cliffs are more common along the Yukon coast than along the lower lying Tuk Peninsula, where a relatively small offshore gradient decreases the effectiveness of wave erosion.

The cliff form is largely a function of the materials of which it is composed. Gravel and sand dominate along the Yukon shoreline but layers of silt and clay are common. The gravel is also common along the Tuk Peninsula, west of Tuk but sands and silts prevail to the east. This is a view of the sand bluffs at the mouth of East Channel.

Where the material is coarse, the cliffs tend to be steep but not vertical, like this cliff at Tuk, for example. This is the cliff in front of Tuk itself. They may even be vegetated like this one near Shingle Point on the Yukon coast, but where the

material is fine grained on the other hand the cliffs tend to be vertical like this one near Kay Point, and if the fine-grained material contains large thicknesses of massive ground ice, ground ice slumps like this one just west of Tuk, or this one at Kay Point, will develop. The banded material in the centre of this slide is almost pure ice.

These cliffed areas may seem desirable as locations for harbours, staging areas etc. because their tops are well above storm surge levels, water depths offshore from them are usually relatively deep, and if the cliff material is coarse, a suitable source of construction material is close at hand.

But the nature of the cliff material is critical. The most ideal location for a deep water port along the southern Beaufort Sea coast might seem to be in the area of Babbage Bight just east of Kay Point because water depths close to shore are deep. The cliffs in this area however are fine-grained and contain considerable massive ice. The vertical bluffs and ground ice slumps like this one predominate, and I think it's hardly an ideal location for the land facilities associated with a harbour, so you have a problem.

The presence of frozen ground and massive ice is also relevant to any pipelines which might come ashore in cliffed areas. In areas like this one near Kay Point massive ice bodies extend below sea level and out under the shallow water near shore. Wave erosion during the August 1975 storm that I showed you the slide of Kay Spit, cut a niche in the base of this cliff and exposed the ground ice behind it. It's hard to see

here in the light, but at the back of the niche there's a continuous white ice area, and this incidentally, is exactly the situation which exists along the cliffs in front of Tuk and it's the major reason why it will be so difficult to stabilize the cliffs at Tuk, and a hot oil pipeline coming in onshore under this kind of condition, I think would be subject to failure.

The second type of coastal land form I'd like to talk about are thermokarst lakes. In addition to the coastal cliff areas there is a second type of coastline in the Beaufort Sea which is basically erosional in nature.

This photomosaic is typical of large parts of the coast along the Tuk Peninsula, particularly east of McKinley Bay.

At first glance the coastline appears drowned, but in fact its outline reflects the breaching by coastal erosion of the lakes which cover much of the Peninsula. These lakes are commonly thermokarst in origin and they result from ponding and differential melting of excess ice in the sands and silts which form their boundaries.

The breaching usually leads to at least partial draining of the lakes and, if this drop in water level is sufficient to enable the lake to freeze to the bottom in winter, to the formation of pingos, two of which are marked on the slide here. This two-pingo lake is about three feet deep.

As coastal erosion continues, the former lake area is deepened, partly because of wave act-

ion and partly because of continued melting of excess ice in the sediments. The area between the barrier bar and the two -pingo lake on this slide is flatbottomed and about ten feet deep, brought low frequency echo sounding shows and irregular sub-bottom , generally less than 13 feet beneath the present bottom. This sub-bottom may represent the boundary between a recent wave-deposited sediments and the older and perhaps still frozen coastal plain sediments underneath.

In any case, a newly breached lake provides an excellent trap for an oil spill. Oil could be carried into the lake during normal flood tides or storm surges. Granted it might be pulled out again by ebb tidal currents but unfortunately, the eastern end of the Tuk Peninsula, where breached lakes are most numerous is also the only coastal segment except for the river deltas, which contains extensive tidal flats. This slide shows exposed tidal flats in and near the two-pingo lake of the last photograph. The two-pingo lake is in the background here of this slide.

Let's turn next to the depositional features found along the Beaufort Sea coast.

Spits, like the ones I have already shown you at Topkak and Kay Points, and barriers like this one at Warren Point on the Tuk Peninsula, front significant portions of most of the coastal segments I have identified. They are particularly extensive near Herschel Island on the Yukon coast, around the old islands -- Pelly, Hooper , Garry etc-- which front the eastern Mackenzie Delta , and from Warren Point east on the Tuk

Peninsula. In these areas they reach lengths of more than eight miles and widths in excess of 200 yards, that's above normal sea level.

As I have already mentioned, they lie in their entirety, below the highest storm tide line and thus are susceptible, at any time to inundation by oil. As well, the shallow lagoons behind them could function in much the same way as thermokarst lakes and act as traps for oil.

The size of the spits and barriers is a function of both offshore gradient and sediment supply. They are largest where offshore water depths are small as they are off the Mackenzie Delta and the Tuk Peninsula, or where the supply of sediment is large as it is in the Herschel Island area where material from the Firth and Malcolm Rivers is added to that supply by cliff erosion.

Their height and cross-sectional form, on the other hand, are at least partially dependent on sediment size. The sandy gravel spits and barriers of the Yukon coast and west of Tuk on the Tuk Peninsula tend to be higher and narrower than the pure sand features east of Tuk. This is a portion of Nunaluk spit near Herschel Island which rises over seven feet above normal sea level, whereas this sand spit at Atkinson Point on the Tuk Peninsula reaches a maximum elevation of less than three feet.

The gravel in coastal beaches, spits and bars and their easy accessibility from the sea makes them attractive sources for borrow materials. They are not thick, however. Both drilling and low-frequency sub-bottom echo sounding suggest that significant gravel

deposits seldom extend more than 15-20 feet below the surface, either on land or in the nearshore water area.

And the last land form type, the river deltas--

THE COMMISSIONER: Excuse me, Dr. Lewis, just a point of terminology. Every -- a lot of witnesses have talked about spits and barriers and barrier beaches. What do you mean by "barrier " ? You used that expression here, and what do others mean by "barrier beaches" ?

A Well--

Q I mean I know what a spit is and I know what a beach is but--

A -- a barrier is simply a spit that's not connected to the land, basically. If you take a spit and chop a hole at its upper end and let the water through, it becomes a barrier. From a practical point of view there's no real difference.

Q There's no what?

A No real difference.

Q Yeah,right.

A They're basically the same features. The barrier beaches-- well htis is just s scientific jargon thing that nobody agrees about, so there's really not much sense me tellin g you what I think, because someone else will tell you something different.

Q Let's forget it then.

A I think the important thing really is they are low-lying features and they're formed basically in the same way, so we can call them the same thing, or probably should be calling them the same thing.

So, to river deltas. Deltas represent the continuing ability of a river to supply and deposit sediment more rapidly than it can be removed by sea waves and currents, that is it's a balance between the power of the river and the power of the sea. In the case of the Mackenzie Delta, the ability of the Mackenzie River to dominate the Beaufort Sea has led to the development of the gently sloping delta plain outside here , which is over 8000 square miles in surface area. Of this surface area, as I have already mentioned, about 1500 square miles may be subject to inundation by storm surges and thus is properly part of the coastal zone. But even this outer delta is river dominated. The clays, silts and fine sands of which it is composed are almost entirely riverine in origin. The manner in which the sediments are deposited however, is greatly influenced by coastal processes.

The most important features of the outer delta plain are the shallow, wide distributary channels; the low, flat vegetated plains which separate the channels; and the lakes which dot the plains. This slide, looking south from the shoreline includes examples of each. Except for the lakes the pattern you see is common on most fine-grained deltas in the world.

The myriad of lakes on the Mackenzie Delta plain, on the other hand, are testimony to the effects of an Arctic environment: specifically to the relatively low plant productivity of Arctic areas and to the presence of frozen ground.

Now outer delta sediments are rich in organic material; in decayed vegetation remains.

This scarp, for example, at the front of the delta is largely organic in nature, but this richness is only relative. On deltas in more temperate climates, lakes are a very short-lived feature of delta plains. They are very quickly infilled by plant debris. This rapid infilling does not occur in the Arctic. So you have, relatively here a large amount of organic material but say compared to the Mississippi Delta you don't have very much at all.

Frozen ground also plays an important role in lake formation and lake evolution. The most significant aspect of this role may be in the effect of freezing on the natural consolidation or settlement of delta sediments under their own weight.

The argument I am about to make is pure speculation. It is not based on hard data but I will present it because of the implications it might have for development on the delta surface and for a pipeline across Shallow Bay.

A delta is a product , not only of the balance between the river and the sea but also of the balance between a river deposition and subsidence. On the Mississippi Delta, buried deposits, which were above sea level less than 500 years ago, are now as much as 65 feet below sea level, solely because of sediment consolidation under its own weight. There's been no change in sea level over the last 500 years. Larger scale tectonic processes are too slow in this time period to account for anything like this amount of subsidence. Unlike the Mississippi Delta though, on the Mackenzie Delta, the ground begins to freeze as areas are built up to near sea

level, as Mr. Shearer has already talked about. Natural consolidation will be stopped at the point in time at which the sediment freezes. If permafrost aggradation is rapid , the frozen sediments at depth will be under-consolidated with respect to the weight of the material over them. Added to this is the continuing addition of new weight in the form of deposition on top of the delta plain. Now if this frozen ground is thawed for any reason, natural or otherwise, consolidation can begin again. On the outer delta plain, numerous lakes appear to have formed in areas of low-centered ice-wedge polygons, possibly because of water ponding, in the polygon areas, subsequent permafrost degradation and consolidation.

The bottoms of most lakes on the outer delta are above sea level; that is above normal sea level, at the present time. But in the Aklavik area, a much older and higher part of the delta, lakes whose bottoms are below present sea level have been recorded. That this could occur in spite of infilling during river floods and deposition of organic debris, may indicate continuing consolidation of the unfrozen sediments beneath the lakes.

Even in the absence of excess ice then-- and there is little in the sediments of the outer delta plain--thaw consolidation remains an important problem. I am curious as to what effect natural consolidation might have on a pipeline across Shallow Bay-- an area which because of the presence of frozen ground at depth beneath it, may be a subsiding older part of the Mackenzie Delta plain. If the rates are in the range of those found in the Mississippi Delta, and I would guess that they wouldn't be

as high as you'd find in the Mississippi Delta, because so much of the material in the Mississippi Delta is organic and it can compress a lot more, but if they were, consolidation of anywhere from 1.5 to 4 feet could occur in the bottom of Shallow Bay over a 30-year period. Well the problem , if that should occur, is not the absolute fact of 4 feet of subsidence underneath Shallow Bay. It's the fact that the pipeline is coming off frozen parts of the delta which are not subsiding so you have differential subsidence; part of it's going down and part of it isn't.

Now, as I say this is speculation. I have no data on it, I know of no other data on it. I think it's a problem which should be looked at.

Elsewhere along the Beaufort Sea coast, that is outside of the Mackenzie Delta, deltas only occupy a small proportion of the coastal zone. There are none at all on the Tuk Peninsula, although the Peninsula itself is composed largely of material deposited in an old Mackenzie Delta.

Along the Yukon coast , the deltas of the Blow and Babbage Rivers are similiar in form and sediment composition to the Mackenzie but are much smaller. The Blow Delta plain covers only 31 square miles and the Babbage 15 square miles. This is in contrast to the Mackenzie's 8000 square miles. This slide looks north over the Blow Delta plain toward the Beaufort Sea.

Unlike the Mackenzie, however, both the Blow and Babbage Delta plains can be covered in their entirety by storm surges, not just to the outer part of the delta plain, but the whole delta plain can be

covered during storm surges. This is a view of the Babbage Delta during spring flooding and the entire delta plain is covered by water. This kind of flooding could be repeated at any time during the summer by a storm surge.

The relatively steep, gravelly fan deltas of the Firth and Malcolm Rivers, on the other hand, do not flood significantly during storm surges, and thus are not as vulnerable to the effects of an oil spill. They also do not contain the low,fine-grained, frozen alluvial flats I mentioned earlier and would not be subject to significant thaw consolidation. This view of the Firth Delta show the aufeis deposits already much descussed in these hearings. Possible borrow pit operations on these deltas have also been covered in earlier testimony by me and by other people.

I've left until the end any detailed discussion of the nature and rates of change of the land forms of the Beaufort Sea coast, because I think coastal stability is the single most important factor in relation to possible development activities.

Under the influence of wave action, particularly during storm surges, the coastal cliffs within each coastal segment I have identified are being cut back and the material moved along shore and deposited either in the form of depositional features; spits and bars , in the case of coarse sediment or offshore in the case of finer sediment. The coastline is thus a very dynamic environment and, if the design of onshore installations or pipelines from offshore doesn't take this into account, they'll eventually fail. I'm not suggesting that

it won't be taken into account.

Cliff retreat is most rapid where offshore gradients are steep and where the cliff sediments contain considerable pore, wedge, or massive ice. Photogrammetric measurements show that this undercut bluff at Kay Point retreated almost 300 feet between 1952 and 1970. Retreat of 25-150 feet over the same period occurred along most of Babbage Bight,east of Kay Point, and other zones of rapid cliff retreat include the Herschel Island area, the old islands which front the Mackenzie Delta and the the Tuk settlement area.

The way in which retreat occurs is unique to an Arctic evvironment and,as I have said, is largely a function of features related to frozen ground. The headwalls of the ground ice slumps I showed you earlier are very rapidly receding. We have measured over 30 feet of retreat in a single year on one, and in other areas undercutting by waves and melting along ice wedge cracks can cause entire polygon blocks to collapse into the sea. This view was taken near Kay Point this past summer, and this is a close-up of the fracture zone at the back of the slumped blocks I showed you in the last slide, showing the exposed wedge ice.

The implications for development of these rates of retreat and of the way in which it occurs must be obvious. I should add only that the rates of retreat are not constant, either seasonally or annually. Most retreat occurs during storm surges; 45 feet of land was lost near the R.C.M.P. station at Tuk during the major 1970 storm, almost one-quarter of the total retreat be-

tween 1950 and 1972.

It will be tempting to obtain sand and gravel for construction purposed from the coastal beaches, bars and spits where continued coarse sediment movement from cliff retreat promises rapidly replenished supplies of high quality aggregate. Spits have extended as much as 2300 feet in length between 1952 and 1970. That figure is for Nunaluk Spit.

In addition however to the biological consequences that may make extraction of this gravel unsuitable, there are a number of things which should be known before permits to mine gravel are granted.

Material supplied to the beaches, bars and spits is in continuous movement along the shore. Extracting gravel will tend to accelerate nearby shore erosion, particularly in the downdrift direction, and the effects of this must be determined. For example, if sand were taken from the beaches north of Tuk, the supply to the beach which fronts the townsite would be interrupted and the coastal cliff there would retreat even more rapidly than it already is. A permanently dredged deep channel into Tuk Harbour would have the same effect unless the dredged material was pumped out downdrift from the channel so it could continue its movement along the coast to end up in the beaches in front of Tuk, and to protect the Tuk Cliff.

The sources of material in the beaches is primarily local in nature. Little coarse sediment will move between the coastal segments I have identified. In some segments, the spits and bars may be relic in nature and material, once removed will not be replaced.

For example, Avadlek spit on Herschel Island was formed from sands and gravels supplied by deposits on the north and west sides of the island, deposits which no longer exist because of cliff retreat.

The dynamic nature of beaches, spits and bars is also relevant to the effect oil from a spill might have on them. During the small August 1975 storm surge I showed you, the beach surface along the spit at Kay Point was cut down by as much as a foot and later reburied by almost the same amount of sand and gravel. Thus oil which was dropped on these features could be buried at any time.

Now, in direct contrast to the coastal cliffs and to the beaches, spits and bars,the delta plains of the Beaufort Sea coast, including that of the Mackenzie are remarkably stable in nature.

Examination of aerial photograph sites spaced over a 22-year period, revealed little shore line advance along the front of the Mackenzie Delta and no evidence of major channel shifts on the outer delta plain. In fact, as this area of the delta shoreline shows , many areas have undergone minor retreat. You can see the wave cut scarp here.

The rate of advance of a delta plain is dependent to a great extent on the balance between river and wave forces. Wave power at the shoreline, in turn, is dependent upon deep water wave conditions and on the offshore gradient. Because the Beaufort Sea is frozen for much of the year and because the offshore gradient of the Mackenzie Delta is one of the flattest of any major

river delta in the world, we might expect that the total annual wave power exerted in the deltaic coastal zone would be very low in comparison with the other major river deltas in more temperate climates.

Under these conditions, you would expect that the Mackenzie Delta would be advancing rapidly, but it isn't, and the only explanation is that river power is also low and now that the river has filled the protected trough between the Caribou Hills and the Richardson Mountains, it is not powerful enough to overcome the-- low as it is-- the erosive wave energy of the open Beaufort Sea.

The lack of major channel shifting on the outer delta plain, may also be related to low river power. This effect is accentuated by the number of channels which discharge into the Beaufort Sea. There are almost 60 with a total width of over 50 miles. This division of a given amount of river power leaves no single channel with enough energy to actively erode its banks, particularly since they are frozen and therefore more resistant to erosion.

This horizontal stability is, in itself, a simplifying factor for possible facilities associated with hydrocarbon development. From this point of view only, the construction which would be unfeasible on most other river deltas of the world may be possible on the Mackenzie. There are , of course, other points of view, some of which I have discussed , which make the delta less attractive than these horizontal stability conditions alone might suggest.

The last aspect of the coastal change I'd like to talk about is the direct effect of sea ice on the coastal zone and on the resultant need for careful selection of locations for the construction of nearshore facilities, such as wharfs and jetties, and I think this can probably best be done with a slide and a question. How would you like to be a wharf or a jetty in the path of this 30 foot high shoreline pressure ridge ? This is at Shingle Point.

So, to briefly summarize and conclude then; the coastal zone is, in most areas a dynamic area particularly so in this part of the Arctic, and its instability must be taken into account if it is to be used for pipelines, staging areas or other shore installations.

Shore installations must be carefully located so as to avoid large areas where large amounts of ground ice are present. A disturbance of the existing thermal regime will serve only to accelerate already rapid rates of coastal retreat. Beach material is primarily local in origin and its removal will lead to increased coastal erosion. As a general principle, therefore, I would recommend that beaches not be considered as sources of construction material. Now I say this just as a general principal, meaning that if permits are ever allowed, that it be required that the downstream-- downdrift and updrift changes caused by removal of that gravel be carefully considered in advance . As I mentioned if you take material off the beaches north of Tuk you're going to effect Tuk and people had better be aware of that.

There are generally few good

harbour locations along the Beaufort Sea coast because of generally low offshore gradients, coastal instability and resultant longshore sediment movement. I've already mentioned the best possibility for a harbour is Babbage Bight but here we have coastal cliffs, rapidly retreating, large amounts of ground ice, so you have a problem with your shore facilities.

The hazards of liquid pollutant spills from shore operations could be minimized if these activities take place in bays or lagoons behind spits or barrier bars, and deltas are among the most complex active environments in the world because of the interaction between river and sea forces. The effects of an Arctic environment must be added to normal deltaic processes on the Mackenzie Delta and these effects are not well understood.Because of this great complexity and because the Mackenzie Delta is a unique North American environment, I would recommend that the development on it be kept to a minimum. Now I don't mean to say necessarily zero, but I think it's an area to avoid if it's possible to do it any other way.

Oil from a spill reaching the nearshore in a given coastal segment will tend to remain in the segment and to move toward its sediment sink, so if oil moves all along the Beaufort Sea coast it'll have to do it offshore. Once it gets into the nearshore zone it will not tend to move long distances along the coast.

The largest areas subject to frequent inundation by sea water and thus potentially, by oil contained in that water are the river deltas, particu-

larly the Mackenzie. Thermal disturbance through vegetation damage could lead to thaw consolidation, even in the absence of excess ice. Other susceptible coastal features are beaches, spits and barriers and the breached thermokarst lakes. Thank you.

THE COMMISSIONER: Well, we'll adjourn 'till two o'clock and then we'll hear from Dr. Milne. Is that--

MR. BAYLY: It's up to you sir.

THE COMMISSIONER: Well, what would you suggest ?

MR. BAYLY: I was just wondering-- perhaps Mr. Milne could briefly outline the Beaufort Sea project. It would just take about ten minutes.

THE COMMISSIONER: Oh what time is it now ?

MR. BAYLY: 12:15

THE COMMISSIONER: Oh sure, let's do that.

WITNESS MILNE: All right, what I'll do is outline what the Beaufort Sea project-- it's objectives are, and a few points on what is it all about. The major objectives are really to be able to put ourselves in a better position; that is Canada in a better position, to answer a number of questions about offshore exploratory drilling in the Beaufort Sea and the sort of questions go like this: What is at threat from offshore exploratory drilling? The biological panel the other day described some to the wildlife that was at threat. These are examples and Peter Lewis has described shoreline

processes, which would be a threat. Secondly, what threats does the marine environment pose to offshore exploratory drilling ? We need there, to get an understanding of the sea ice as it pertains to the operation of drill ships, how it could threaten their operations. What are the typical weather conditions if such a thing can be described ? What are storm surges like ? are they predictable and so on-- is there any method of predicting all of these environmental features which could be used to advantage by offshore exploratory drilling systems. Thirdly, how would pollutants be transported from drilling sites and to where ? These involve oceanographic studies, mostly movements of sea ice and ice climatology. How can changes in the marine environment be identified and monitored? Clearly, here we're looking at baseline studies which mean essentially, what is the marine environment like now, in most of its constituents, as many as one can identify, so that in the future,if there is large scale development, could we determine what the effects of that development might be. Finally how can offshore drilling be conducted with a maximum but acceptable risk to the environment, and I think my assessment of how one might answer these questions is,we can respond to the questions in terms of , to varying degrees-- that is, in some cases the information we have to respond to those questions is fairly shakey, and not very clear, in terms of best quesses. In other cases the information base is quite good, mainly on oceanography and sea ice, On the biological side it tends to be much more uncertain.

The cost of the project, overall estimated at about 12 million dollars, and -- which essent-

ially covered,partly by,in House, ongoing Government support, people's salaries, overhead, and new funds to the tune of 6 million dollars were plugged into the system over two years, part of which was 4.1 million dollars from the Arctic Petroleum Operators Association, under their APOA project number 72, which was called the Beaufort Sea Environmental Project, by them.

I think one of the things that has happened during this project,which is quite important, and that is the direct involvement of industry with government, which has forced, I believe, industry to pay attention to every aspect of the studies which have been going on, rather than standing to one side and watching the activity and not being too concerned in it. So that has been a great advantage here; that if somebody's watching over you to determine how their money is spent, it has a two way benefit. Also , all these activities regarding government and industry funding and the joint activities came under an industry, government agreement which prescribed that the outcome of the studies, and in a very general way should be available by the end of 1975. It was not very specific on that point. The main purpose of that rather loose deadline was to ensure that there would be some information available so that a drilling authority could be considered for 1976.

I think I'd like to stop there unless somebody wants to specifically ask questions which are in their mind.

MR. BAYLY: Perhaps, Mr. Commissioner we could break now for lunch,and if we could

start right at two o'clock we could possibly finish the evidence in chief by coffee break.

THE COMMISSIONER: Well look, why don't we start at--

MR. GOUDGE: I would think we'll be able to accomodate Mr. Milne. We can focus our questions on him this afternoon, and I would see no difficulty in--

THE COMMISSIONER: Well, why not start-- it's not even 12:30 yet. Why not start at 1:30 ? Let's try to get back at 1:30 and then we can do justice to Dr. Milne's presentation and not have him feel, or any of us feel that we're rushing through it. So let's do that. Let's come back at 1:30.

(PROCEEDINGS ADJOURNED AT 12:20 P.M.)

(PROCEEDINGS RESUMED PURSUANT TO ADJOURNMENT)

MR. BAYLY: Mr. Milne, if you're ready, perhaps we could begin with your evidence, at the introduction on page 1.

WITNESS MILNE: All right then, I'll begin.

This is the introduction. What I'm going to read is the evidence which is a cut down version of the preliminary environmental assessment, which has been published as the Beaufort Sea project technical report number 39. The introduction as follows.

Drilling for oil using ice-strengthened drill ships is proposed for ice-free periods starting in the summer of 1976 at two sites. These sites are shown at the back of the document in Figure 1, and I think you're all familiar with where they are. These sites are inaccessible during the winter and spring to any existing drilling systems. The scale of activites for 1976 is small, therefore the only real major impact on the environment would result from oil discharged into the sea in the event of an underwater blowout. Although the possibility of a blowout occurring is remote, it cannot be ignored. There is a whole series of possibilities and conditions that will determine the severity of the impact of a blowout on the environment such as:

Whether it is just a gas blowout; if it is gas and oil, and what is the discharge rate of the oil; whether or not it is self-sealing; when

during the drilling season the blowout occurs; how long it would run wild before a relief well could shut it off; what kind of oil it is; the probable effectiveness of proposed oilspill countermeasures; where the escaped oil would spread to; how weather conditions, such as storm surges, wind and sea state would affect the spread of oil and the ability to contain oil; once spread to coastal areas and in the sea ice, what its effect would be on organisms; would there be any changes in the climate; how long would it take for wildlife populations to recover; would there be local and possibly international ramifications to depletions of some wildlife species.

This testimony is an environmental assessment and assumes the hypothetical worst case oil well blowout in a scenario form, and examines the nature of the transport and fate of oil in the Beaufort Sea.

Assuming a "worst-case", and that's purposely put in quotation marks, because one can think of cases that are even worse, sub-sea oil well blowout, major conclusions are as follows:

The blowout would run wild for at least one year, until a relief well could bring it under control. Access to either site for relief well drilling in any summer is not guaranteed. Even though a wild well could discharge oil for a year or more into the Beaufort Sea's ice, any premature melting which would be caused would be indistinguishable from natural ice-cover fluctuation, hence no climate changes should

be attributed to oil in the volumes expected. Oilspill countermeasures for 1976 --

THE COMMISSIONER: Excuse me, Dr. Milne, I don't altogether follow that. Premature melting owing to the contact of oil -- owing to a film of oil under the ice?

A Owing to the fact that the oil, is black absorbs the sun more readily, and tends to melt the ice faster.

Q Yes, I understand that, but then you say that would be indistinguishable from natural ice cover fluctuation.

A Yes, the amount of extra ice that could be melted by oil contamination, that amount would be indistinguishable from the -- or insignificant compared to the natural fluctuations in ice cover in the Beaufort Sea.

Q Right. All right, I'm with you.

WITNESS MILNE: The wildlife most seriously damaged would be seabirds. It is judged that none of the damage would be irreversible, but that recovery could be as long as a decade in some cases. Except for birds, the economic values of Beaufort Sea wildlife are small compared to oil industry expenditure. The birds are a continental resource with a high indirect economic value. The major values threatened must be judged primarily on sociological and environmental grounds, not economic.

So that's the summary of the

conclusions. The next heading is exploratory drilling in 1976, and I want to just read out "The Concern".

Almost the whole of the Canadian portion of the continental shelf of the Beaufort Sea has been subject to permits by oil companies for a number of years. Seismic and other geophysical surveys have been carried out fairly extensively over the whole area. It is regarded as promising with respect to gas and oil reserves. To date the only drilling which has taken place offshore in the Beaufort Sea has been from artificial islands constructed in shallow water close to the Mackenzie Delta. However, at least some sectors of the industry are now anxious to see exploratory drilling in areas of deeper water farther offshore.

The Canadian Marine Drilling Ltd., Canmar, is a subsidiary of Dome Petroleum, and plans to drill two wildcat wells in the southern Beaufort Sea in the summer of 1976. There are two drill ships, and I understand there's a third one, the halvedrill has been purchased in Norway, which could mean three systems might be in the Beaufort Sea by the end of 1976.

In the future, an expansion of exploratory drilling, perhaps followed by the drilling of production wells and the laying of pipeline networks will clearly have extensive environmental and sociological implications which will have to be dealt with by appropriate authorities. However, of immediate concern is how the Beaufort Sea environment

might be degraded by Canmar's proposed exploratory drilling in 1976. The major immediate concern is the threat of marine underwater oil well blowouts.

Three questions arise. What is the probability of a blowout? What are the probable consequences of a blowout? What is the capability to control the blowout and to clean up oil which escapes control? This assessment is mainly concerned with consequences and clean-up, but it also must deal with the nature of ice conditions in the Beaufort Sea as it influences the viability of drill ships' operations, and in particular, their ability to drill a relief well.

To date, drilling authorities in the Arctic and elsewhere offshore have been granted where it is possible to extend the drilling season sufficiently long in order to implement measures to control a wild well. However, such precedences cannot be strictly adhered to at the proposed drilling sites. It is evident from the description to follow that if a blowout were to occur in the latter part of the drilling season of 1976, the earliest completion date for a relief well would be toward the end of September, 1977, and there is no assurance that the well would not run wild for yet another year.

Drill ship operations on the continental shelf of the Beaufort Sea differ significantly from those in areas explored hitherto. The major difference is the presence of sea ice which would preclude drilling operations from ships for the

greater part of the year, and in some cases for the whole year. For example, if Canmar had been granted drilling authority for operating with two drill ships starting in the summer of 1973, they could possibly have completed two wells in 1973, would have been able to conduct virtually no drilling in 1974 and could have started two, but at most completed only one, in 1975. If a blowout had occurred in late 1973, and had not been self-sealing, it would not have been possible to start a relief well in 1974. One could have been started in 1975, but it is not certain that it would have been possible to complete it.

Canmar has incorporated special ice resisting features in their drill ships and supply vessels in order to combat ice intrusions. The extent to which these features may be successful is touched on later.

The problem of drilling a relief well is aggravated by the fact that both of the Canmar sites are located within a transition zone between the offshore polar pack to the north, and what late in winter becomes landfast ice to the south. During winter the transition zone contains ice which is moving and actively shearing. Although ice breaking vessels could be used to extend the drilling season into the fall, the ice in this region can be too thick in winter to be handled by any existing ship, including the largest icebreakers, but at the same time it is too mobile to permit the use of ice as a platform from which to drill a relief well. Only in a summer period of

perhaps three months, and sometimes not even then, is there a time interval in which drill ships can operate.

The probability of an oil, or oil and gas well blowout, is judged to be in the range of one in one thousand to one in ten thousand for each well drilled. As more wells are drilled, the cumulative probability of a blowout would increase. However, if experience is gained in drilling in the Beaufort Sea, the risks per well could be reduced.

The next heading is "Some Effects of Crude Oil on the Aquatic Ecosystem".

The effects of the interaction of crude oil with marine organisms are complex and are extremely difficult to predict in advance of a polluting incident. Direct mortality of marine life through poisoning,coating and asphyxiation, is usually associated with coastal oil spills. There is also a physiological damage to organisms such as reduced fertility and lower body resistance to infection, generally resulting from prolonged exposures to sublethal levels of oil. Disruption of normal migratory and spawning behaviour and feeding patterns -- habits, can occur due to the animals avoidance reactions to oil. Sometimes there is absorption of oil particles into suspended solids which eventually settle to the sea bottom. These sedimented oil particles could be chemically re-induced into the food web by benthic feeders. Changes in water chemistry resulting from the introduction of water-soluble components of crude oil can upset the natural balance of dissolved gases and nutrients.

The extent and severity of damage to Arctic marine organisms by crude oil depends on numerous factors such as the amount and type of crude oil spilled, the location of the spill, the time of the year, the presence of sea ice, water turbidity, and obviously the abundance and distribution of plant and animal life and their exposure time to the oil.

The next heading is "Blowout Scenarios and the Effectiveness of Oil Countermeasures".

Canmar has taken the question of countermeasures in the event of a blowout seriously. To what extent can their proposed countermeasures reduce the damage which is to be expected in the event of a blowout? A realistic examination of this question leads to the conclusion that although under very favourable conditions a large fraction of the oil released might be successfully dealt with, the percentage of the time of a blowout when these very favourable conditions would occur is an estimated 45%, so that a large fraction of the oil would escape. Indeed, since the rate of flow of oil used in a scenario is entirely hypothetical, that is the actual flow could vary from a small fraction of a hypothetical 1,500 barrels a day to several times this, it would seem necessary to assume in any blowout scenario that the oil which escapes is not much less than the oil released by the blowout. No control systems at present, including the ones proposed by Canmar, other than sealing off the well by the drilling of a relief well or some other technique, shows promise of reducing the possible damage

from an oil spill by a factor of ten. That's pretty conservative, a factor of ten.

"Preliminary Environmental Assessment". The method adopted in this assessment is to compare the potential for damage which would result from an oil well blowout occurring at either of Canmar's sites number one and two, and at a hypothetical site number three located in the landfast ice zone. Now I've labelled these sites one and two. Site number one is a site which you have seen on a map closer to shore. Site number 2 is one further offshore. Site number three is embedded in the edge of the landfast ice. Pathways and fates of oil are described in scenarios, or narrative; and these are used as the foundation for assessing the impacts on wildlife.

The next section is called "The Beaufort Sea", is a description of the whole setting. Now the geographical setting has been covered adequately this morning, and I think I can just go over, just skip around that. It covers the physiographic features, and the coastal features, of the Beaufort Sea. So I'll skip over to the sea ice features, on the top of page 5.

The growth, movement and decay of the sea ice in the eastern Beaufort Sea, is influenced by the polar pack interacting with the coastlines, the Mackenzie River and the Arctic climate. The average movement of the offshore pack is caused by mean wind stresses over the Arctic Basin, resulting in a clockwise gyre, or ringlike movement. The clockwise speed of the

ice near the rim of the gyre varies from zero at times, to as much as 25 kilometres a day for short periods in the springtime. Its' average yearly speed is about 3 kilometers per day.

In summer, the polar pack consists mainly of multi-year floe ice, pressure ridges, rotted first year ice, leads and large pools. In the winter, growing first year ice replaces the open water and the wind-stresses on the ice produce flaw-leads and new pressure ridges. Under short-term wind stresses, the centre of the gyre, or this great pan of ice offshore, can shift, resulting in onshore or offshore movements. Onshore movements in winter and spring are limited by the growth of landfast ice in the coastal bays and shallow shelf water; the landfast ice generally extends seaward to depths of 25 meters. In the summer however, excursions of polar pack ice into the southeastern Beaufort Sea are controlled by the vast flow of fresh water from the Mackenzie River, local wind fields and the shallow shelf waters.

Extensive scours are produced on the sea-bottom of the shelf by the onshore and alongshore movements of sea ice. These are produced mostly in winter and spring by the grounding of under-ice projections such as pressure ridge keels. Scour trenches generally do not exceed 2 metres in depth, but in places are as much as 6 meters deep . Scouring is common in water depth of 15 to 45 meters, with a maximum activity at 30 meters, within the transition zone.

During November and December, the landfast ice grows in thickness and increases its area in a series of steps seaward, depending partly on onshore winds. These winds consolidate loose floes at the fast ice edge where they remain in place during offshore drift. By April, the landfast ice has grown to a thickness of 2 meters.

Although the polar pack is sometimes blown well offshore in a light ice year, its' nearshore boundary in winter usually lies over the 500 meter depth contour near the edge of the continental shelf. Lying between this pack edge and the fast ice is a transition zone of deforming, sporadically moving, heavily ridged and highly irregular ice. THis zone, of active shearing, provides open water, albeit temporary and variable, in winter and spring. The transition zone ice often resembles the polar pack but includes an increasing number of pressure ridges and more first-year ice as the landfast ice is neared.

The beginning of breakup in the southern Beaufort Sea is first evident as early as March with the widening of flaw-leads west of Banks Island, under the thrust of east and southeast winds. The simultaneous westward and clockwise movement of the gyre away from Amundsen Gulf produces another long flaw-lead at either the seaward edge of the landfast ice, or further offshore, in the transition zone. Additional radial leads, perpendicular to the coast, also open in the transition

zone, forming part of an extensive interconnecting lead system. By April, ice from Amundsen Gulf moves westward to fill the increasing spaces of open water between the fractured ice of the transition zone. If you refer, you could if you wish refer to figures 2 to 6 at the back of the document which indicate the major ice movements observed using the NOAA satellite imagery from March 11 to June 21. These describe the gradual development of leads offshore, and if you just turn briefly to those, and I'll just describe. Each one of these diagrams from figure 2 on through to figure 6 show the location of the Canmar sites, and these images from 1975 show that where the Canmar site number 1 is located is often in an open lead, as early as March, and that the ice movements onshore and offshore of the polar pack against the landfast ice continually open and close this lead. We also get a clockwise movement of that offshore ice.

The resolution of this imagery is somewhere about half a kilometer, so it doesn't show all the detail that one would expect to see. I think the message here is that both sites are located beyond the landfast ice, and in the more inshore Canmar site is in a zone of active shearing, and has more open water in its vicinity that the site further offshore.

By mid-May, the Mackenzie River is in freshet and one month later, considerable open water exists in the nearshore waters of Mackenzie and Kugmallit Bays. By early July the coastal fast ice

has disintegrated and moved offshore with the polar pack. If however, westerly winds prevail throughout most of the summer there will be a heavy ice year such as in 1974 when the boundary was roughly on a line between Herschel Island and Atkinson Point on Tuktoyaktuk Peninsula. Generally the summer and fall pack ice edges are distorted southward with protuding tongues and eddies of floe ice. Thus in summer, it is likely that the floe tongues will cause extensive interruptions to drill ships operating at the Canmar sites. The main characteristic of the ice in the southeastern Beaufort Sea is the extreme variability of its extent and movement which render terms such as "average ice concentrations" and "average ice year" of little use.

I'll now go on to describe some of the significant oceanographic features.

In the southeastern Beaufort Sea the Mackenzie River outflow meets and mixes with the salt water of the Arctic Ocean over much of the wide continental shelf. The river is in freshet from mid-May to early August. During the late winter and spring the flow is reduced to 1/10th of this rate as it spreads out under the landfast ice. The plume of fresh, muddy water flows out over the top of the more saline ocean water, but when the Beaufort Sea is covered with ice, or in the absence of winds, this plume will turn eastward along the shores of Richard Island and Tuktoyaktuk Peninsula toward Amundsen Gulf.

The turbid, fresh water layer

from the river is normally from two to five meters in thickness, however this thickness increased to eight meters or so in the heavy ice year of 1974, as a result of the damming effect of the polar pack pressing close to shore. The fresh water layer on the surface and those beneath can have -- and the salt water layer beneath -- can have quite different currents, both in direction and speed. When offshore winds drive the fresh surface waters northward, deeper oceanic waters must replace this water in an underflow. Conversely, the fresh surface layer thickens with onshore winds, with a resulting expulsion of saline waters offshore. These counter-currents can cause deep draught ice floes, and thin brash ice to move in opposing directions.

An important consequence of the river flow in the winter and spring is that the shallow inshore waters are brackish east of Richards Island and along the Tuktoyaktuk Peninsula. Hence there is over-wintering habitat in the shallow lagoons, estuaries and breached thermokarst lakes well suited to non-oceanic species of fish, invertebrates and micro-organisms.

Another feature of the river is its high mud load, hence low light penetration which inhibits primary biological production except where river borne nutrients can be utilized outside the turbid plume.

Storm surges or wind tides occur frequently in the southeastern Beaufort Sea. THese are increases and possibly decreases in sea level, other than tidal, caused by a wind-driven

pile-up of water on the continental shelf. This can be a negative pile-up. At Tuktoyaktuk, between 1962 and 1973, 22 positive and 5 negative surges, that is associated with offshore winds, were recorded. Two were more than 2 meters above normal tide fluctuations of .3 meters. Ten occurred during the light ice year of 1963, since there was a great deal more open water available. The offshore condition necessary for a storm surge is a fetch of 50 kilometers or so of open water containing ice concentrations of 3/10 or less, and that is with minor ice floes. So that there can be a rapid movement of the water surface in response to the wind. Surges are normally accompanied by large wind-waves, rapid coastal erosion and inundation of coastal lowlands. Driftwood strand lines, two meters or so above sea level, show that the coast line from Herschel Island to Cape Bathurst has been subjected to storm surges. A winter surge of one meter was recorded on January 6, 1974, generated by the passage of an intense low pressure weather system through the northern Beaufort Sea. It is supposed that the ice slackened toward the north, with offshore winds, and then closed with strong inshore winds. After the wind shift, the ice concentration was low enough to generate water movements toward the shore. Although this surge was not in itself a damaging event, winter surges could cause unusual displacements in the landfast ice and complicate the prediction of oil transport in the event of a blowout.

In summary, large positive

storm surges require extensive open water and are caused by strong west or northwest winds. Open water is also desired for offshore drilling using ships. High winds are more likely in September and October, and the two meter surges at Tuktoyaktuk occurred on the fourth of September, 1962, and the fourth of October, 1963. Oil from a blowout near the end of the drilling season could co-exist with a storm surge to transport oil inshore into lowlands.

The next section really is a description of the wildlife in the Beaufort Sea, and I will ask the question at this moment whether I should pass over that, to include -- there's quite a bit of this material included later on in connection with the scenario, because I realize there has been quite a lot of coverage with the biological panel that was here earlier.

THE COMMISSIONER: Well, I'll leave that up to you Mr. Bayly. I haven't read this so you would know better than I whether it's appropriate to --

MR. BAYLY: A large amount of this has been gone into by the large panel that we did produce, sir, and perhaps we could leave it out at this point, and I'll just ask Miss Alison to check over it and see if there's anything she'd like Mr. Milne to read, in particular.

WITNESS MILNE: Shall I then skip it for the time being?

MR. BAYLY: Skip that for the

time being, and we may come back to portions of it.

THE COMMISSIONER: Yes, I think we did, yes, we heard a lot about that. Carry on.

WITNESS MILNE: Start at the top of page 9, which is "Scenarios For Oil And Gas Well Blowouts In The Beaufort Sea". I want to make clear what that heading means, "Oil and Gas Well Blowout" is what's being considered, because oil and gas usually co-exist in a blowout, if it's an oilwell blowout.

The present plans of Canadian Marine Drilling Co. Ltd., Canmar, are to send their two drill ships into the southeastern Beaufort Sea as early as possible in the summer of 1976. Assuming that 1976 will be a light -- a year of light ice, the earliest date that the ships may begin drilling is about the first of August. If it is a heavy ice year, it is unlikely that the ships could proceed to their drilling sites at all.

The two drilling sites proposed for the summer of 1976 are shown in Figure 1, in the rear of the document. Site one is in a water depth of 26 meters, located about 46 kilometers seaward of Tuktoyaktuk Peninsula; Site two is in a depth of 58 meters at a distance of 83 kilometers offshore of Pelly Island. Both sites are situated in the transition zone ice, that is, beyond the depth of 25 meters. The drilling season is not likely to extend beyond mid-October, allowing only 2½ months at either drill site to drill down to possible petroleum-bearing strata. The likelihood of a blowout is increased toward the end of

the drilling season, as petroleum is encountered.

Assuming the postulated blowout occurs on the fifth of October, the second drill ship could, at most, begin work on drilling a relief well, but would be unable to drill down to the petroleum-bearing horizon to control the wild well before freeze-up. In this event we would be faced with a free-running blowout and little hope of controlling it until at least ten months later, in the following summer. Even then it would depend on having a favourable ice year to bring it under control.

In some geological oil-bearing structures, debris entrained in the gas and oil within the well-bore can gradually quench or reduce the flow of a wild well. However in the worst case the well could free-run throughout the fall, winter and spring, until the summer of 1977 when action could resume to drill a relief well to bring the blowout under control by that season's end.

"The Underwater Oil and Gas Well Blowout". What would this blowout be like? It is postulated that the initial flow of crude oil could be 2,500 barrels per day, and that this flow could decline to 1,500 barrels a day, or in one month's time, as the local region of the reservoir is drained. 1,500 barrels a day equals 240 cubic meters of oil per day, and a cubic meter of oil is about a ton approximately, or 87,600 cubic meters of oil a year, assuming the well does not self-seal. Accompanying this would be about 1.2 million cubic feet of gas per day, which accompanies

the crude oil to the sea surface, so you can visualize this gas and the oil coming to the sea surface.

Since the blowout orifice is at the sea bottom, gas rises to the water surface in bubbles, carrying the oil with it, in effect creating a bubbler system, which circulates bottom water toward the surface. At the well-head orifice on the bottom, the oil is churned into droplets which rise toward the surface at varying rates. Some of them will coalesce to form larger drops; others, being very small, will remain suspended in the water column for some time and therefore will be moved at the whim of the sub-surface ocean currents. A contingency decision may be made at this point to fire the blowout if it is not already on fire. Assuming calm waters, little ice and negligible currents, it is possible that 90% of the oil could be burned off, although this has not been demonstrated. The tarry residue would be retained locally by the natural water-circulation generated by the rising bubble stream. What is does is forms a wave ring. This simplification breaks down when we consider ocean current, surface waves and moving ice floes. The following paragraphs will describe the possible transport and eventual fate of oil following such a blowout.

This part describes the transport of oil during the ensuing fall and winter, after a blowout occurs.

The two proposed drilling sites are strongly influenced by the Mackenzie River. When offshore winds blow, the fresh water of the river moves

out over the more saline, cooler sub-surface waters. This surface layer of river water is muddy and can be up to eight meters thick. Often the currents in these thin surface waters are quite different from those beneath the sub-surface, more saline water. The surface waters are driven mainly by the wind, while the sub-surface waters are moved by oceanic influences. To complicate flow prediction, young ice or thin rotten floes, which draw little water, commonly move in the direction of the surface currents while the deep-draft old floes can travel against this surface current, under the influence of sub-surface currents. Often, there will be no simple puddle of oil to burn. If a large ice floe happened to float over the site of a burning blowout, the fire is likely to be extinguished.

Violent storms are common in the fall of the year. In October, offshore winds drive the newly-forming ice away from the shore and out to sea. Strong northwest winds follow in November, can whip up the waves and drive the ice back to the coast. It is not likely during the late fall that an ignited blowout will remain on fire. The oil will be blown by the wind, be emulsified to some extent, and eventually be driven toward the shoreline of Tuktoyaktuk Peninsula. Here, the Mackenzie River flow will transport the oil along the shore of the peninsula to the northeast.

Modest, one meter storm surges occur in mid-October under the thrust of onshore winds, so that the innermost reaches of breached thermokarst lakes, bays and lagoons could be contaminated

by oil. As the sea calms between storms, and the landfast ice begins to form from new grey ice and floe fragments, some of the oil will remain mixed in with the surface of the landfast ice. The most rapid reduction of the flow of the Mackenzie River occurs in November and by mid-month the flow is 15% of the mid-summer flow. At this time, the ice forming on the continental shelf can move westward as the offshore influence of the northeast river flow diminishes. What I'm trying to say here is that as the river flow diminishes, its offshore influence diminishes. It is flowing toward the northeast but in this time the influence of the oceanic circulation begins to take over, so that later on by mid-November, it is postulated and understood that at the Canmar site, the general westward gyre circulation is taking over.

Marine inshore and offshore clean-up equipment, consisting of floating booms, devices to separate oil from water, and floating incinerators, will be completely inoperable much beyond freeze-up in October. Canmar may attempt to re-ignite the blowout by dropping incendiary material from aircraft at the site. These efforts could be frustrated by intruding ice floes which frequently snuff out the flames. There will be discontinuous movements of multi-year pack ice over the site, remnants of past season's first-year ice and new ice. Leads in this ice can form, freeze and be compressed, the new ice being crushed and mixed with oil.

Storm surges sometimes occur during the winter in the southeastern Beaufort Sea.

THese would not necessarily result in oil reaching the frozen shoreline, but could produce a rim of oil along the coastal landfast ice. Since a winter surge can cause a one meter rise in sea level at Tuktoyaktuk, oil would contaminate any ice-free shores but would not enter ice-covered bays and lagoons.

By late January, the landfast ice has formed, though incompletely, to seaward, and the ice in the transition zone is moving irregularly westward. Within the transition zone there is often a wide lead or networks of leads and cracks caused by the offshore retreat of the Arctic pack when south or southeast winds blow. It is estimated from satellite imagery, again I refer to the ones showing the sequence of development of open water from early spring into late spring, that Canmar's site number one will be in open water or water covered with new grey ice an estimated 50% of the time from late January through to early May. In contrast, Canmar's site number two, the one further offshore, will be covered with transition zone ice an estimated 90% of the time for this period. Therefore the two proposed sites are distinguished by their position relative to this predictable offshore lead, with the result that a large fraction of the oil released from a sub-sea blowout would have distinctly different histories during the winter and spring, for both these sites.

IN some years, possibly one year in ten, site number one, closer to shore, could be incorporated in landfast ice. I've said previously

landfast ice generally goes out to 25 meters, but in some years it goes considerably further. Satellite imagery has been examined which showed that the edge of the landfast ice on June 11, 1973, and June 14, 1974, was well landward -- that word should be"landward", at site number one. However, if this site were in the landfast ice in the spring of 1977, the action of the blowout would maintain an open pool above the well which would directly contain a depth of oil equal to one-half the ice thickness. Oil accumulated beyond this volume would flow out over the top of the ice and be absorbed in the surrounding snow cover. Up to 90% of the oil contained within the pool could be burnt, but this, as a proportion of the total oil flow, will depend on the diameter of the pool and the rate at which it can be burned. These will be determined by local conditions and the accessibility of the site. What I'm leading up to here is that a site in the landfast ice doesn't necessarily produce as much oil that escapes westward.

So what has happened up to this time, we had the blowout, and we've gone through the winter, and into the spring, and now -- at least into the winter -- and now I'm interested in what the distribution of oil could be like on the fifth of May. Now this is quite important because during the period up to the fifth of May is when a lot of the migratory wildlife come into the Beaufort Sea.

Focussing now on a blowout at Canmar site number one, that's the one just off the landfast ice and south of the one further offshore, in

the period from late January to early May of 1977, oil will rise into any lead over the site left by the northern retreat of the pack and will mix with newly formed frazil ice blown toward the north side of the lead. Should this lead close, the oil rising will also flow under the ice. The lead could vary in width as the offshore pack moves westward, so that new ice which forms in the lead could be compressed as the lead closes to form oiled pressure ridges along the north boundary of the landfast ice. Early in winter, some of these ridges could attach themselves to the seaward extending landfast ice, but by late January they will move westward as part of the transition zone ice and will exist of multiple lines of narrow ridges adjacent to the north boundary of the landfast ice.

Apart from active shear leads and northward branching flaw leads, ice concentrations in the transition zone will be 10/10ths. Hence, with minor exceptions, ice excursions over site number one will inhibit ignition of the blowout unless extraordinary and costly efforts are made to maintain open water artifically in this region of moving ice. Canmar proposes to fragment the ice with explosives to promote more effective burning. This technique is likely to be effective during times when ice motion has temporarily ceased. Gas accompanying the oil, though eventually escaping through cracks and narrow leads, will fill under-ice voids and provide a smooth surface to aid in the spreading of oil, rapidly and thinly, under the ice. Beyond the horizontal range of gas escapement, the oil

will flow under the ice to fill voids and cavities. The actual under-ice area contaminated would depend largely on the speed of the ice cover moving over the blowout site; and at Canmar site number one, an estimate of the average speed is one kilometer per day to the west, when it is ice covered.

For an oil discharge rate of 1,500 barrels a day, or 240 cubic meters a day, the width of the swath of oil under the ice is likely to vary between .4 kilometers to 1 kilometer; I have since modified that to be a little narrower than that; depending on the permeability of ice to gas. On the other hand, when the offshore ice retreats and then advances, the westward motion could average ten kilometers per day. This is during the time the gyre is actually not scraping against the landfast ice, it tends to move faster, when it's against the landfast ice, it tends to stick. The oil could be more localized in east-west ridges and displaced under adjacent ice. The total length of the oiled trail to the west from late January to early May could range betwen 300 to 500 kilometers. That takes us pretty well to Barter Island.

In summary, assuming a blowout occurred on October 5, 1976, at Canmar site number one, the oil could be dispersed in early May as shown in Figure 7. I have a slide of this, which if people want to see what I think it might be like, or you can refer to Figure 7.

MR. BAYLY: Perhaps we could show that slide. It would be perhaps easier to --

not everybody in the room has a copy of Figure 7.

A
This shows an estimate of what the oil dispersal could be like, from a blowout occuring in the late fall of 1976, and what the picture could be like on May the fifth; and here is Canmar's site. This is a depiction of the buildup of the landfast ice during the fall, and late winter, and indicating that there is a distribution likely of about 2,200 cubic meters of crude oil, distributed rather thinly through this great area of landfast ice. And it also indicates that in the fall, that because of the river flow, in the open water, it will take us up toward Sachs Harbour and south Banks Island, and distribute this oil quite thinly through this area toward Banks Island and the mouth of Amundsen Gulf. I'm quite convinced that that does occur because the other October, when we went into Sachs Harbour in October, this whole area was contaminated by river sediment, so that's quite valid as far as I'm concerned.

Later in the fall, as the landfast ice builds up and this general gyre circulation begins to take over, it sort of bounces up against it and down, and up from the landfast ice, and therefore most of the oil, a large percentage of it would reside at the surface of the ice, and then the pressure ridge is extending through this area, with a small fraction of it being under the ice. You're looking at about 2,300 cubic meters, or somewhere the order of about 2,600 tons, spread very thinly along this region up here. Now this depiction of how it is is misleading

because -- could be misleading -- because you can't draw a line thin enough, but the point that I'm going to come to is that when the spring comes, this area is precisely where the wildlife come, and that's quite important. THese are the main migratory groups along this area. So this path does extend over here, about 400 kilometers from the site, over here by May the fifth, in this narrative.

Q And Mr. Milne, when you say "over here" for the record, you're indicating westward towards Alaska.

A That's right. It would go -- perhaps I've made as far as Point Barrow, perhaps not that far, depending on the year, and the average speed of the gyre at this location.

Maybe, while I'm up here, I could just have the next slide too, with the Canmar site number two which is further offshore, we'd have a somewhat similar situation existing during the buildup of the landfast ice, where the oil could be accumulated, about the same amount, maybe slightly less, 1,800 cubic meters, in the landfast ice as it builds out from the shore. In the late fall we'd have about the same distribution up here, but then because this is not in the main shear lead, most of the time, we would get a trail which would result from these sporadic irregular movements of the gyre as it moves clockwise in this area. These could be disconnected as here, but it would go about the same distance off to the west.

Now the message I will mention

here is this, as far as wildlife problems are concerned, and migratory routes, this is perhaps less threatening than the site nearer to shore, simply because it's in a less -- it's not in a main east-west lead that opens up in the springtime, and is a main migratory region, an active zone of active shearing.

This is a depiction of what might happen if for some reason Canmar decided well, they're going to drill in the landfast ice zone. What it really means is that the bulk of the oil which would have otherwise gone off to the west, would be confined to this area, here, and in such a way that quite a large percentage could possibly be burned off, the part that would otherwise go over here.

A blowout at Canmar Site number 2 on the fifth of October -- oh, perhaps I've missed a bit here, on the top, I started on the top of page 12.

In summary, assuming a blowout occurred on the fifth of October, 1976, at Canmar Site number one, the oil could be dispersed in early May as was shown in that first slide in Figure 7. Assumptions are that: 3,500 cubic meters will be blown toward the coast by winds associated with a storm surge on October 10, that would be in the late fall, which is a very likely occurrence; 5,000 cubic meters will have been dispersed northeast towards Banks Island in the fall, 22,000 cubic meters will be dispersed in the growing and the seaward extending landfast ice, part toward the northeast until mid-November, and the remainder to

the west until late January; finally, 2,300 cubic meters will be distributed along the north edge of the landfast ice, 400 kilometers to the west, or 75 kilometers west of the Alaska-Yukon border as far as Barter Island.

Q Mr. Milne, was that 2,300 or 23,000?

A 23,000, I'm sorry. That's roughly about 2,600 tons.

A blowout at Canmar Site number two, which was the second slide I showed, on the fifth of October this year, would likely produce a somewhat different distribution of crude oil by the fifth of May, in 1977. At site number two, it would seldom be in open water in the late winter, so that from late January to early May, the oil would most likely be encapsulated within the ice of the transition zone. Prior to this, much of the oil would be incorporated in the landfast ice as depicted for Site number one, although somewhat less since the westward ice circulation would be established sooner offshore.

For comparison with the two Canmar sites, a hypothetical landfast ice site number three, at a depth of 18 meters, was shown on that third slide. The only significant difference in the distribution of crude oil from October fifth blowout at site number three would be the containment of the oil within a restricted area in the landfast ice by late January. If all the oil from late January until break-up of the landfast ice is eventually burnt, then we would have the disposition as shown in that third slide, with no

trail-off, virtually none trailing off far to the west.

The oil contaminated landfast ice would cover an area of approximately 7,700 square kilometers. That's in each case, it's approximately that amount. Most of the 22,000 cubic meters of oil in the landfast ice would likely to be concentrated in narrow bands or ridges parallel to the coastline. This is because of the way the landfast ice tends to form, and as a result of onshore and offshore stiction. A useful visualization is that the oil coverage would be equivalent to forty bands of oil .3 centimeter thick and one meter wide, each spaced one kilometer apart. In the area south of Banks Island, shown contaminated by 5,000 cubic meters of oil, the average oil concentration would be one-half the amount computed for the landfast ice. These concentrations also apply to the oil dispersals shown for site number two and three. I just wanted to get this sort of image of how much it would look like; one can divide it up in different ways.

Any consideration of weathering which would apply to a large fraction of the total oil discharged from a blowout at site number one, and which could reduce the oil volume by 30% has been ignored. Weathered oil would be difficult to burn. In contrast, oil trapped in the ice remains in its original state. What I mean here is the oil which is incorporated within the ice. That oil droplets rising from the sea bottom well-head have different residence times in the water column and can be dispersed widely depending on the subsurface currents, has also been ignored. That's an

awkward sentence, but what it means is some of them rise faster than others, and the ones that rise very slowly and which are small, can travel in subsurface currents.

Therefore one might expect to have a considerable number of droplets, perhaps 2% of the total oil volume, incorporated into the ice sheet well beyond the estimated swath widths. This is the swath painted by the underwater blowout as the ice moves over the top of it. It must be emphasized that the swaths of oil under the transition zone ice would not be continuous ribbons of oil, but would often consist of disjointed segments. It is likely that the detection in the spring, of the fragmented oil trails originating from site two, in particular could be aided by radio beacons deployed near the blowout site at intervals throughout the winter.

Next, I want to touch on the "Seasonal Effects On Oil In Ice During May, 1977". Now, it's clear that something significant must be said about May, and this is what's significant. It's the time when oil begins to emerge to the surface, because of the increased solar radiation and so on.

Early May is a critical time in the Beaufort Sea. The sea ice ceases growing; the brine in the ice would be replaced by oil which will slowly rise to the surface of the ice. The sun's heat absorbed by the dark-colored oil within the ice, will create melt pools which form natural containers for the surfacing oil. At the same time, the offshore leads form a network of highways and feeding locations for

migratory and resident wildlife. Much of the oil locked into the ice throughout the winter and spring, resulting from a blowout at site number one, that's the more southerly site, would be released precisely in the main migration routes.

Early May is also the optimum time to initiate disposal of oil by burning. The oil which has been trapped within the ice in a fresh state, will burn easily as it emerges; however, the weathered oil at the surface will not readily burn. Judging from the scenarios of oil dispersal, 60% of the oil from site number one could be weathered and about 40% from site number two. The unweathered portion would emerge from within the ice as small scattered patches and pools extending along paths extending 400 kilometers to the west. Burning significant fractions of this oil, perhaps at most 20%, is questionable in view of the vast areas to clean up, the short two weeks or so of time available before the oil surfacing would become too weathered to burn, and the poor flying weather existing toward mid-May.

Now I'll go on to what I think might happen to the oil movement from June to early July, which is from through the breakup in 1977.

In JUne, the ice is rotting rapidly and constantly moving at the whim of the wind. Gradually, in early July, the landfast ice breaks up and moves offshore. Larger floes break up into smaller floes. With air support, maintenance of a conflagration at a blowout site would become easier since the floes

will be rotten and more permeable to gases. By early July the Canmar tugs and oil clean-up equipment could attempt to proceed to the blowout site to corral the oil. However, in heavy ice years, migration of floes near site number one, and more so at site number 2, would frequently frustrate the effectiveness of oil clean-up activities. At hypothetical site number three, that's in the landfast zone, oil containment and burn-off would be interrupted briefly as the landfast ice breaks up and moves offshore allowing marine equipment to approach the blowout site.

In spring 1977, the Mackenzie River will be at its maximum flow. The surface water, in calm weather, will carry the landfast ice offshore to the northeast, while prevailing winds will tend to move the pack ice to the northwest. A likely result will be that prior to early July, this interaction of winds and currents will move the oil fixed in the landfast ice, and transition zone ice, into the Arctic pack. There the oil will weather and merge with rotting floes and reside within the open pools and leads at the southern periphery of the gyre. Consequently, most Canadian shoreline contamination other than that from mid-October, 1976, could be caused by oil escaping containment and clean-up from early July to the end of summer. That is before it would be possible to drill a relief well. Much of the oil discharged earlier will have travelled westward with the pack ice to the north of the Alaskan coast as far as Point Barrow.

"The Climatic Effects". The

amount of weathered oil which would be dispersed from a single oil well blowout running wild for a year, would be unlikely to have any effect whatever on global or even local climate. While it is certain that oiled ice will melt much faster than clean ice, natural fluctuations in the yearly ice cover would mask the extremely small changes which would be caused by oil in the volumes assumed.

Now we get on to the following year's relief well situation; "Relief Well Drilling in the Summer of 1977". We're now at the top of page 14.

In the meantime, plans for relief well drilling will be laid by Canmar. Following news of a blowout in October, two of Canada's largest icebreakers may be overwinterd in the southeastern Beaufort Sea to assist a Canmar drill ship to maximize its 1977 drilling season. Plans will have been set for burning the oil expected to emerge from the sea ice in early May. Also, supplementary offshore and inshore booms, skimmers and burners will be mobilized in the delta. Ice-strengthened tugs and aircraft support will be prepared for the anticipated oil countermeasures operation in the summer. Steps will be taken to set up a comprehensive environmental prediction system to support marine operations and to predict oil-slick movements.

Drilling a relief well to control a blowout is a more complex operation than either wildcat or delineation drilling. Despite better knowledge of geological formations, it cannot be expected

that less time will be taken to drill the oil reservoir than it did to drill -- less time will be taken to drill to the oil reservoir, than it did to time taken to drill the original well. I hope you went through my stumbles there.

The scenario assumes sixty days of drilling in 1976, before the hypothetical blowout occurred. Spudding-in for a relief well at either Canmar site could occur on July 15, 1977. Assuming there were no significant interruptions, control could be gained by October 1, 1977. From July to October first, the blowout could have discharged, that is during the summertime, 21,000 cubic meters of oil, and some 3.1 million cubic meters of gas to the sea surface.

As with the original well, the blowout preventor, or BOP stack of the relief well will be placed in a jetted out cavity or in a silo in the sea bottom to protect it from intruding polar floes in the summer. And now, I think it's perhaps worthwhile, showing some of the slides following. These are referred to as Figures 10, 11 and 12.

The main reason for showing these drawings, taken from satellite imagery in August 31, 1973, is to show that at some time there are likely to be significant interruptions of drilling procedures at either of the Canmar sites, shown as number one, number two. Now, this line depicts a cloud edge which obscured observation here, at this date, however these are quite large, one kilometer size. The dots which are visible here refer to one kilometer diameter floes intruding toward

the Canmar site number one, and then Canmar's contingency plans of -- pardon me -- Canmar's operating plans, these are their alert zones which define the different kind of operations they would conduct if icefloes intruded into any one of them. So, at this time, when observations was conducted here, right in the optimum time of the drilling season, in 1973 which was a good ice year, we do have a considerable number of possible interruptions.

Again, on August 26 of this year, which was a heavier ice year, number two was completely in 10/10 pack ice, number one was obviously inoperable. The next one, please.

And here in this year, about the same time, a moderately decent ice year, Canmar site number two is completely under ice here, and the edge of the pack, and the Canmar site number one has very large floes intruding around it. I must stress here that the number of observations you can make during the summer are very limited, with ERTS imagery, and it's just what you can see, so it doesn't really tell you very much about how many interruptions there are likely to be.

THE COMMISSIONER: Dr. Milne, excuse me, if you had a blowout at site number two, and you went there under conditions such as those prevailing in '74, when it was covered by pack ice in the summer, I take it is what you said, wouldn't that make it easier to drill a relief well. Couldn't you set up on the pack ice?

A These edges are moving, subject to the local weather. They can move very rapidly.

This is in effect, not a fixed system; in fact you look at the images close around this and you find that this edge has moved down here, and it'll move back. What you can glimpse just through the cloud, but it's very mobile, this ice is extremely mobile here.

THE COMMISSIONR: I see, and your hypothetical site number three, is landfast ice, where you could actually drill your exploration well through the ice. That supposition's fair, is it?

A Yes, well, there's another factor which I haven't enlarged on , and that is the duration of what you might call the open water season on say, based on the average over the last twenty years, is much higher the more southerly you go. In other words, in the land fast ice, you have a longer operating season than you would have here, and you have a much longer operating season than you have here, because of the location of the site with respect to the normal migrations and location of the pack ice edge; so what I'm concluding here , is that in my comments is that, in that site and that site you have really different durations of open water seasons on the average.

MR. GOUDGE: Could you identify those sir as site number, I take it, number one and two --

A Number one, number two.

MR. BAYLY: What you've said, Mr. Milne, as I understand it, is that you would have a larger number of open water days at site one than at site two.

A Correct.

THE COMMISSIONER: Well, maybe I missed something, but I thought site three, hypothetical site three, was an exploration well drilled in landfast ice.

A It's drilled in the landfast ice zone, --

THE COMMISSIONER: But in open water.

A -- in open water.

THE COMMISSIONER: Right. Sorry, I follow you now; but drilling in landfast ice is technologically feasible. Isn't that what they do in the high Arctic, or the central Arctic, or wherever they're drilling.

A Yes. I think in this particular case sir it's -- one can devise a possibly landfast ice location -- one could presumably under some circumstance take mobile equipment onto the landfast ice and possibly build an artificial ice platform, but the chances of doing that are not very good, because it's not like landfast ice in the archipelago where you have a much longer time of stable ice than you do in this location, it builds up during the winter, and you don't have the long period of time, degrees days of freezing to permit an ice platform to be built up to support the drill rig, nor is there any assurance that the landfast ice does not move as a result of winter surges, and in fact it does and has been measured to move considerable distances during the late winter and early spring, a matter of 100 meters or so.

THE COMMISSIONER: So that, where they're drilling for oil and gas in the archipelago, in the Sverdrup Basin, I think it's called, they are able to drill on ice and through ice that is stable, year round, is that the situation?

A No, it's not stable year round, it'll be stable for when the ice is thick enough to support equipment along till when it begins to decay in mid-May, early June.

Q So they have a winter drilling season?

A THat's right.

Q What I'm getting at I suppose is, we have been drilling; first of all we have these artificial islands here in the vicinity of the delta since, we've been drilling in these artificial islands immediately offshore for two or three years, we've been drilling in the archipelago for two or three years I suppose. Is there any succinct way of -- well, what I suppose I'm getting at is -- was there a Beaufort study project prior to the embarking upon a drilling program in the archipelago?

A No, there was not; but at the same time I'm aware that in the archipelago that the ice conditions there are more benign than they are in the Beaufort Sea. The fast ice is known not to move as it does in the boundaries of the Beaufort Sea; is known to have a longer duration and account has been taken of the possibility of being able to drill a relief well in offshore locations. Artificial islands, that's another

in mid-October, then you would expect a considerable amount of oil to reach the coast during the summer of 1977, during that drilling season. This assumes that a relief well is successful in 1977; and I mentioned also the intrusions of the pack ice which could disrupt a relief well drilling activity, so, and also the movements of the free oil will be governed by the winds and local surface currents. In the absence of winds, the surface currents have minor tidal components but are mostly from turbid fresh river water extending to beyond the Canmar sites and trending to the northwest to Amundsen Gulf; so in the summertime you have quite an extensive river influence and as we mentioned before, that the river will normally trend off to the northeast, it should be, to Amundsen Gulf, as a result of Coriolis force.

Onshore and offshore winds will modify this flow of the river, and this was outlined earlier. It is clear that west and northwest winds will drive floating oil to the sea coast along the shores of Richards Island and Tuk Peninsula. If coincident with these winds there is a large expanse of open water, a storm surge could be generated. Minor surges of 1 to 1.5 meters are common throughout the summer; for example in 1963 between July 5 & October 16, there were ten surges. One exceeded two meters and seven had amplitudes in excess of one meter. Most years experience three or more surges in the summer.

Weather systems move through, as to the southern Beaufort Sea, at approximately two week intervals, in the summer, resulting in an equal

probability of northwest and southeast winds. Therefore the 21,000 cubic meters of oil, which is the amount assumed that would escape from July -- in this open water period -- if not burnt or contained, will fan out in all directions to the boundaries and edges of the ice-free waters of the southeastern Beaufort Sea, with a slight bias to the northeast due to the river flow. If we now assume a paraffinic type crude oil, 30% of this volume, or the more toxic light ends or aromatics, could evaporate within 48 hours. Of the remaining 14,700 cubic meters, 50% of this or 7,350 cubic meters could impinge directly on the shorelines of Richards Island and Tuk Peninsula. The greatest concentrations would paint the exposed coasts, headland, lowlands, inlets and so on between Kugmallit Bay and Baillie Islands. This is because of the location of the site as postulated, that's where it would go; so what we're looking at is about 7,000 odd cubic meters which could fan out in -- which would be the fraction ending up on the shore after a major amount has evaporated and some of it has gone off to the north.

Oilspill countermeasures can reduce this quantity substantially, although their effectiveness both offshore and along the shore will depend almost entirely on periods of relative calm. The oil and gas blowout envisaged is unlikely to remain ignited in winds and waves, since the wide-spread oil film could remain below its flash point. This is because the water's cold, and knowledge today indicates that if oil is spread on cold water, it is too cold to ignite easily, unless it has quite a thick film.

Winds, waves and accompanying surface currents would also reduce the effectiveness of containment booms. For the month of July, August and September of the years 1953 to 1972, offshore winds with speeds less than eleven knots, were recorded about 45% of the time. Hence, a rough estimate of oil escapement from the blowout site is 55% in the summertime. Inshore, the countermeasures effectiveness could be poorer. In selected bays where efforts could be concentrated, again 55% escapement is likely; therefore using percentages of 55% offshore, and of the total amount inshore 95% escapement, then an estimated 7,350 cubic meters of weathered oil originally destined to reach the shoreline during the summer windy period would be reduced to about 3,800 cubic meters, as a consequence of counter measures. This would flow to the shore at a rate of about 1,300 cubic meters a month.

This volume of oil could be added to the weathered residue of the 3,500 cubic meters of oil already on the coast from the fall of 1976, immediately after the blowout occurred and before freeze-up, that was. Assuming that weathering would leave 70% of this, the fall contribution would have been 2,450 cubic meters of oil. Taking into consideration the 400 kilometers of coastline between Kugmallit Bay and Baillie Islands most likely to be affected, the 2,450 cubic meters from October 1976 will paint the coastlines with an amount of oil equivalent to a band one meter wide by a little over half a centimeter thick. Then, from the summer, the following summer, the 1,300 cubic

meters of oil per month would continue to increase this thickness at the rate of a little less than half a centimeter per month during the summer of 1977; so if you can get that picture of this equivalency, this is really what I'm trying to drive at. It's clear also that it would be possible for this oil to be concentrated over a much shorter coastline, depending on the actual weather systems, which would be encountered during that particular summer.

It is probable that half of this oil would be immobilized on spits, bars and headlands, leaving the remaining half to contaminate estuaries, lagoons and low-lying coastal plains. During storms, oil can be incorporated into the sediments of bars and spits and later can be re-exposed to float on the water as these sediments erode some indeterminate time later.

So, just to sum up what I've been saying, there's a site comparison with regard to environmental threat from oil.

The fate of oil from both Canmar sites and hypothetical site number three has been described under the assumption that a blowout occurred on October 5, 1976. There would appear to be significant differences amongst the sites regarding potentially damaging effects on marine wildlife; and as I pointed out before, the distribution of oil is different, and that's shown again on Figures 7, 8 and 9, which you have already seen. It is evident that oil blowouts at any of the three sites could be equally damaging to the coastal environment along Tuk Peninsula.

Oil from hypothetical site number three, in the landfast ice zone, would be least damaging to offshore migratory and resident wildlife, assuming that the oil can be burnt off or otherwise disposed of in a pool in the ice or polynia in the fast ice during springtime.

Oil from site number one would be most damaging to offshore migratory and resident wildlife because of its proximity to the main east-west lead immediately offshore of the fast ice. A large fraction, perhaps 60% of the 23,000 cubic meters of crude oil discharged from late January to May 5, could be remobilized in this lead.

Oil from site number two would appear to be less damaging than from site number one, to offshore wildlife since much of the oil discharged offshore in the transition zone would be more widely dispersed and less available to contaminate the main east-west flow lead used by resident and migratory marine mammals; and that's not necessarily for birds, I'm saying mammals here.

MR. GOUDGE: I wonder if there's a major break in Mr. Milne's paper; would it be appropriate to break now? We've been going for over an hour and a half.

THE COMMISSIONER: Sure, fine. We'll take a coffee break and then perhaps another one later on, because we started early.

(MINUTES OF ENVIRONMENTAL SOCIAL COMMITTEE TASK FORCE ON NORTHERN OIL DEVELOPMENT MARKED EXHIBIT 465)

(PROCEEDINGS ADJOURNED AT 3:05 P.M.)

(PROCEEDINGS RESUMED PURSUANT TO ADJOURNMENT)

THE COMMISSIONER: Well, we'll come to order again.

MR. BAYLY: Mr. Milne, will you continue with your evidence?

WITNESS MILNE: I will now continue describing the effects of oil on biota in the Beaufort Sea and these are described in the context of the scenarios that have been developed up to this time, and they're divided into seasons, as was the -- as were the scenarios. In the following -- this is the middle of page 16 -- in the following impact assessment, the effects of oil on seasonal and resident biota of the south-eastern Beaufort Sea are considered. Short-term and chronic responses to oil contaminated habitats at different seasons of the year are predicted. Emphasis is on critical niches and life patterns such as migrations in leads, and overwintering in coastal bays.

So now I'll touch on the autumn of the year, which is the period following the imaginary blowout on October 5th.

Now the imaginary blowout on October 5, 1976 at either C anmar site would deposit several thousand cubic meters of weathered oil on the north-west shoreline of Tuk Peninsula, in Kugmallit Bay and along the north-east coast of Richards Island. Compared to predicted quantities discharged offshore in the landfast ice and transition zone, the coastal spill would be relatively small; nevertheless, it would

produce significant contamination of about 400 kilometers of shoreline and embayments. A reduced impact of this pollution on marine mammals and birds is predicted in autumn. Most sea birds, geese and shore birds have migrated out of the Mackenzie Delta area by late September and October. Ringed and bearded seals are present but not concentrated, and could probably avoid slicks or contaminated inshore waters. The Arctic fox is confined to the coastal tundra until the landfast ic e forms. The intertidal zone of the Beaufort Sea is virtually barren and damage to invertebrate fauna would be minimal. During October or November, depending on when freezeup occurs, the bears immediately migrate south, thus reaching more seals. 86% of bear tracks observed in October are headed south. Many bears move out onto young sea ice barely thick enough to support them. In years when large amounts of pack ice are blown south to the mainland coast such as in 1970 and '75, bears are more abundant near shore. It is not known whether or not polar bears actively avoid oil contamination. However, it is predicted that tens of bears could be in contact with oil, especially in the landfast ice zone near the blowout site. However, the major ecological concerns in coastal waters are the freshwater and marine fishes which, during October and on through the winter, feed or migrate along the shallow inshore waters of Richards Island and Tuk Peninsula. Overwintering concentrations exist in Mason and Mallik Bays on Richards Island, Tuktoyaktuk Harbour, and in numerous interconnecting embayments of Tuk Peninsula.

An estimate of the standing crop for Mackenzie region freshwater and anadromous fishes is over 500 tons.

The same protected waters are nurseries or rearing habitat for fry which are swept down the Mackenzie River soon after hatching. Fisheries surveys have revealed that over 60% of the total fry catch from lakes, streams, channels and coastal waters of the Mackenzie Delta region are concentrated in low salinity, shallow inshore waters. Here also are foun d several species of normally marine fishes such as herring, four-horned sculpin and Arctic flounder, which are able to tolerate low salinity waters. These move inshore as large schools by early summer to spawn in the shallow coastal waters of Tuk Peninsula. By autumn large numbers of herring fry are still inshore and could be subject to oil contamination.

Coastal bays and lagoons behind barrier beaches are natural traps for oil floating to the shore. Features of these habitats are frequent fall storm surges and between times, low rates of water exchange; both increase the chance of oil persisting in these highly productive fish habitats.

The significance of heavy fish kills of both breeding and juvenile components of Arctic freshwater and marine stocks may be high. Undoubtedly the recovery of the populations to pre-spill status will be slow. Growth of the fishes is slow over a life span of 15 to 20 years. Maturity is usually delayed until age five years or older. Only

once in every five or more years are successful year classes produced by many species. Repopulation in local areas of fish depletions is possible by migration of unaffected fish from unpolluted areas of the Mackenzie drainage and nearshore waters. This assumes the fishes' food supply, mainly benthic invertebrates, have recovered from oil pollution of the embayments. If c onsiderable quantities of oil are buried in the bottom sediments, thus acting as persistent toxicants to bottom dwelling organisms, recuperation of fish stocks could be delayed for at least a decade.

Now we'll go onto the winter season. Up to 15,000 ringed seals and 2,500 bearded seals are concentrated in the leads of the transition zone from Herschel Island along the mainland and north to the west coast of Banks Island. Of these numbers, 35% of the ringed seals and 50% of the bearded seals are distributed along the active east-west shear leads between Herschel Island and Cape Bathurst, which could be contaminated by tens of thousands of cubic meters of oil in the event of an oil well blowout at either Canmar site, but more so from site No. 1. It is highly likely that these mobile animals will be in contact with oil to varying degrees.

Whether or not large seal kills will result from an oil blowout will depend on the duration of the seals' exposure to oil and their general state of health. Both species -- that is the ringed and the bearded seals -- travel the network of leads in attempts to remain in ice-free ones, thus minimizing

the maintenance of breathing holes. As a result, the probability of oil contact is high. The time of exposure to oil may, however, be short, depending on choices of escape routes. Experimentally, oiling of ringed seals has demonstrated that healthy animals are not permanently damaged by short periods of physical contact with Norman Wells crude oil.

Bearded seals feed mainly on zoobenthos, such as gastropods, sea cucumbers, and large crustaceans, hence oil contamination of the ice or water surface will not deplete their food supply.

In winter, ringed seals feed almost exclusively on Arctic cod, the most abundant offshore fish which inhabits the underice surface and surface waters of the leads. Extensive oil contamination of the lead network will indirectly or directly degrade the local cod population by smothering underice algae and crustaceans upon which they prey.

Lack of food, lack of snow cover for birth lair construction, and heavy winter ice in the transition zone cause large natural flucuations in productivity, nutritional states, and population sizes of ringed seals. These in turn reflect on the distribution and survival of their major predators, the polar bears. For example, there was almost a 50% decline in numbers of ringed and bearded seals as well as a tenfold reduction in the pupping success, both attributable to the heavy ice year of 1974. This resulted in redistribution of polar bears and poor survival of cubs. Environmental stresses will compound

the debilitating effects of oil pollution; laboratory experiments show that ringed seals stressed by transportation and handling succumb within a few hours of exposure to oil pollution levels which are relatively harmless to unstressed animals. Natural wildlife mortality as opposed to that attributed to exploratory drilling activities, will be difficult, if not impossible, to determine. However, it is critically important to ensure that detrimental effects of exploration do not coincide with, and thus aggravate, stresses that seals and other wildlife populations may already be experiencing through natural causes.

If oil-related seal kills did take place north of Richards Island and Tuk Peninsula, the recovery of the bearded seal populations would be slow. Since offshore leads are used for feeding as well as for breeding by this species, substantial numbers of breeding adults, adolescents, and pups would be killed simultaneously. In contrast, the ringed seals prime pupping habitat is the stable landfast ice to the east of the Mackenzie Delta and beyond potential winter contamination from a free-running oil well blowout. The potential kill of sub-adult ringed seal population could be 30% or greater, although its recovery is insured by isolation of its breeding stock.

The offshore leads in the transition zone, critical to the survival of overwintering ringed seals and breeding and feeding bearded seals, are consequently important areas for feeding polar bears and scavenging Arctic foxes. Even though

a major seal kill might not affect the eventual recovery of their populations, reduced numbers over several years will certainly affect the distribution and possibly the survival of the polar bears, and to a lesser degree, Arctic foxes. The harm caused by oiling a bear's insulating fur or by the ingestion of oiled seal flesh and blubber is not known.

So that section is really covering the resident populations. Now we're moving onto the springtime, essentially the months of May and June, and what might happen there.

Wildlife in the sub-Beaufort Sea exists in a harsh environment, not in the sense of low temperatures alone, but from a very abbreviated season of phytoplankton production. In this regard, May, June and July are the most important months of the entire year, when intense spring illumination permits photosynthesis to proceed at a high rate. Animal life, particularly the zooplankton, are adapted to a short feast and thereafter a long famine. Within a few weeks, the invertebrates accumulate nutrient reserves for the production of eggs and to sustain them through the winter. Oil contamination of the surface and open water invertebrate communities could seriously impair their ability to capitalize successfully on the peak availability of food. The quantities of oil and its dispersion from a single blowout from either Canmar site are not likely to threaten long-term survival and recovery of Beaufort Sea plankton communities. However, local depletion

of the important spring production and of dependent invertebrates in the leads and ice of the transition zone could directly affect the migrant whales and sea birds which rely exclusively on these habitats for spring feeding. As in winter, the active leads off the mainland coast in Amundsen Gulf and west of Banks Island are also important spring habitats of polar bears and seals. Adult ringed and bearded seals breed from mid-March through mid-May. Although not gregarious animals, there is a seasonal aggregation of over 50,000 animals in the transition zone when they haul out to moult in late June, immediately prior to breakup. The annual moult is known to be stressful for the seals. In spring the decrease in blubber can reduce the animal's weight by 23 to 40%. Oil from a previous seven-month accumulation in the transition zone and fresh pollution in the vicinity of the drillsite could contaminate large numbers, potentially the majority of bearded and ringed seal populations. The added stress of the contact with oil during the moult may be potentially lethal because of the low state of health of these animals.

It is not surprising that over 80% of polar bear sightings from late March to mid-May are concentrated on 9/10ths to 10/10ths ice cover near active leads such as those in the vicinity of Baillie Islands. Ringed and bearded seals are concentrated here where the combinations of currents and winds for a persistent open pool -- that sounds funny -- provide a persistent open pool and allow the

animals easy access to the air. This type of habitat is mainly restricted to the transition zone where leads are widening in the springtime. A blowout at either of the two Canmar sites could contaminate to varying degrees up to one-third of this critical habitat during the spring of '76-'77. Avoidance of contaminated leads by moulting seals is not assured, hence if seal kills occurred they would affect dependent polar bear populations, some of which are international. Some fraction of the Arctic fox and ringed seal populations of the Beaufort Sea are probably also international.

Annual spring migrations into the south-eastern Beaufort Sea by whales and birds occur in May and June when the impact of an oil well blowout would be greatest. 5,000 beluga whales and several hundreds of bowhead whales push through the leads and cracks of the transition zone in late April through to June. They feed on the concentrations of Arctic cod and macro-invertebrates which are attracted to the leads by inc reased light and food. Beluga time their arrival for calving in Shallow and Kugmallit Bays, and rely on the early spring food supply to prepare them for their month-long fast in estuarine waters. The modes of oil interaction with whales are unknown. Possibly a local depletion of white whales' food in a network of leads along the mainland coast could alter the health of pregnant cows and subsequently the success of the year's calving. The presence of an oil slick contaminating the leads

can complicate the whales' freedom to manoeuver and delay their arrival in the calving grounds. A loss of an entire year's calves either from short-term human disturbances or by natural causes would be of moderate significance to the population. To the Inuit who depend on the white whales' presence in Kugmallit and Shallow Bays for income and recreation of the annual hunt, any displacement from traditional calving grounds would be unfortunate. It is clear, however, that oil from a blowout at either Canmar site is likely to greet large numbers of whales moving in leads; for example, 1,500 whales were observed in a polynya 25 kilometers north of Toker Point (or about 35 kilometers south of Canmar site No. 1) in July '74. The prevailing ice conditions of the transition zone blowout will dictate the degree to which migrating whales would be exposed to oil.

Migrating sea birds will die in large numbers if oil, almost regardless of its type, quantity and state of weathering, is encountered in the transition zone. Several million sea birds, geese and shore birds migrate eastward along the mainland coast during May and June. The leads along the edge of the landfast ice are particularly important; here the diving birds such as oldsquaws and eiders comprising as much as 90% of the entire offshore bird migrants, can rest and then feed on the benthic and nektonic fishes and invertebrates found in shallow continental shelf waters. Often the birds search at high elevations for patches of open water, including

surface melt ponds when leads are scarce. Open water attracts most birds which have been observed to change their intended direction of flight to light. Oil-contaminated leads, open water and melt ponds appear to attract diving birds, if the oil is in sufficient quantities to calm the water surface. Since very small quantities of oil,often a few drops, can destroy the birds' thermal protection and waterproofing, the kill of sea birds could be very great. The ecological significance of the resulting kill,possibly 15% or more of the entire sea bird population, would not be disastrous over the long term, This assumes a no population depletions occurred during the earlier migration along the Alaskan and Yukon coasts , that there would be little additional mortality of nesting, feeding, staging, and moulting birds, and that there would only be localized short-lived pollution of the barrier beaches and coastal bays, river estuaries, etc.

These are poor assumptions. The hypothetical blowout as viewed on May 5, as was shown on the diagram before, could contaminate the leads and ice of the transition zone with an estimated 25,000 cubic meters of oil spread as far west as the Alaskan mainland. The American coastal barrier beaches and lagoons are extremely crucial resting and feeding stops for migrating birds. Large numbers of eiders, oldsquaws, loons and gulls would have further chances of encountering polluted melt ponds on the ice surface, and along portions of the mainland coast such as Richards Island, Tuk Peninsula, and the Yukon coast which

will be polluted with oil, especially during the open water season of 1977.

In 1964 (that's 11 years ago) a 10% natural kill of migrating birds was reported along the Yukon coast. That was a heavy ice year, '64. An estimated 100,000 eiders and other diving birds starved when the leads of the transition zone closed and refroze. Such a high natural mortality may not be common, however bird populations appear to recover quickly provided the lead habitats are available in subsequent years. If a large reduction in birds were to occur during the 1977 spring migration, the population could probably recover, if staging, feeding and breeding habitats are protected. The transition zone would be free -- oil free in the following years, assuming that a relief well successfully quenches the blowout in 1977. If there is a heavy ice year, such as in 1974, and a drill ship is not able to return to the blowout site, the wildlife mortality would be several times greater.

We now go on into the summer following the assumed blowout, this would be the summer of 1977, the months of July through to September.

During the summer the hypothetical blowout of 1976 could contaminate 400 kilometers of mainland coast with the partially weathered remnants of 3,800 cubic meters of oil. The barrier beaches, sandspits, lagoons and bays of Richards Island, Tuk Peninsula and to a lesser degree, parts of the Yukon coast, would be most directly affected. Colonial nesting birds such as terns and gulls as well as some

shore birds, could be affected by oil fouling nesting sites. Many other bird species could be oiled during marine feeding forays in the nesting phase. Later from mid-July to late August many birds seek protection in coastal waters during the moult period. A general movement of birds occurs from freshwater lakes where they nested and raised young, to these coastal bays. This movement, that is during August, is likely connected with the moulting of flight-feathers, as a result tens of thousands of flightless oldsquaws, scoters, scaups, mergansers, and other species are concentrated in lagoons and other sheltered areas behind barrier beaches, especially along Tuk Peninsula.

Swans and geese which nest in river mouths, estuaries and salt marshes, may suffer long-term damage to their nesting and feeding sites. Inundations from storm surges and high river water levels occasionally flood nests and drown young. Oil carried inshore in concert with a storm surge would not only eliminate the annual production of young, but could also pollute nesting sites in successive years. Chronic damage to vital nesting areas could significantly delay the recovery of bird populations following offshore kills.

Fall staging is another critical time for shore birds, geese, brant, oldsquaws, scoters and scaups. These birds concentrate in traditional coastal habitat, particularly along the Yukon coast from Shallow Bay to the Blow River. Their staging areas are usually coastal marshes which are

frequently water-covered each summer and offer nutritious sedges and grasses for birds prior to their migration southward. Snow geese, for example, gain up to one-quarter of their body weight during staging, in preparation for long-distance flights over unproductive taiga. Brant are even more dependent on coastal littoral zone for their diet of aquatic plants. Oil which contaminates shoreline and lagoon vegetation could be redeposited in bottom sediments, thus affecting long-term plant productivity and benthic invertebrate foods. Oil could even be directly ingested by grazing swans and geese in search of roots and bulblets.

During the peak of the summer insect season, large herds of caribou and reindeer retreat to the Beaufort Sea coast, including Richards Island and Tuk Peninsula. The onshore winds of the Arctic coast reduce the severity of insect attacks, but more often the animals wade and swim in near-shore waters and bays seeking relief. It is probable that these large ungulates could encounter floating oil along the mainland coast and protected bays, however the effect of such encounters is unknown.

Oil contamination of the near-shore waters in the outer Mackenzie Delta is probable during the whale calving season; strong north-east winds can drive the oil slick against the river flow and eventually inshore. An oil spill in open water could presumably be avoided by these animals, as apparently occurred with migratory gray whales off Santa Barbara, California. Since whales apparently do not feed in

river plume waters, any depletion of summer fish stocks or benthic organisms by inshore oil pollution would likely go unnoticed by beluga. If the whales are forced to leave the contaminated part of the estuary, this interruption could reduce the survival rate of calves for that season. The subsequent recovery of the population may only be a matter of years. More harmful to white whales than oil pollution may be the future levels of summer noise and activity from machinery, ship and aircraft. If focussed in Shallow and Kugmallit Bays, the whales could be forced into less suitable calving grounds.

In summer, the ringed and bearded seals are scattered along the mainland coast offshore and near Banks Island. Oil slicks could easily be avoided by these animals. Although their food habits are varied, the coastal bays and lagoons east of Cape Bathurst are common feeding sites. If heavily polluted with oil, these productive waters containing benthos and fishes could be rendered useless to seals. Franklin Bay, for example, south-east of Baillie Island, seems to be a nursery for a large decapod crustaceans. These invertebrates are important in the bioeconomics of the Arctic as they are part of the food of the beluga whales, sea birds and fishes, as well as the seals. The decapods themselves feed on phytobenthos, detritus and small crustaceans, forming a close link to the primary part of the marine food chain.

Now I'm just switching over

here to the middle of page 2, the value of marine Arctic wildlife to humans. The values.

It is clear that the economic value in absolute terms of the harvest of fish and wildlife resources in the Beaufort Sea is very small indeed when compared with the expenditures involved in oil exploration or with the value of resources which it is hoped will be revealed by this exploration. On the other hand, it is also clear that to the people involved these resources have a meaning and importance which greatly exceeds their economic value. The same can probably be said of the importance of the birds to the people in Southern Canada and the United States. The significance of the effects of an oil spill on these fish and wildlife populations therefore depends very strongly upon subjective value judgments, and is not easily quantified.

I just go into the conclusions which repeat those which have been made in the beginning but are in more detail.

Extensive drilling operations in the Beaufort Sea will have substantial environmental and sociological impacts whether or not any major polluting incident occurs. The situation will have to be examined and dealt with by other appropriate authorities as it evolves. However, the drilling of two holes in the summer of 1976, which is the subject of immediate urgent concern, will not produce a sufficiently large increase of activity in the Beaufort Sea that a major impact will result unless an oil

blowout should occur. Therefore attention is focused on that possibility.

Probability of an oil blowout in the summer of 1976. It is very difficult to ascertain the probability of a blowout, since the number of offshore blowouts worldwide which produce substantial oil pollution has been too small to produce a satisfactory statistical base, and the particular conditions in the Beaufort Sea are unusual. Nevertheless, on the basis of information given by representatives of the industry and by DINA and DEMR, the probability of an oil or an oil and gas well blowout is judged to be in the range of 1/1,000 to 1/10,000 for each well drilled. This doesn't say anything about the cumulative probability.

Environmental threat from a blowout at proposed 1976 --

THE COMMISSIONER: Excuse me, sorry, Dr. Milne. Just that last remark of yours, you said,

> "The probability of an oil or oil and gas well blowout is judged to be in the range of ten to the third power, I suppose that is, and so on for each well drilled."

That is if you take each well, as if no well had ever been drilled or no other well would ever be drilled, that's what you come up with?

A Yes, that's correct. I think one can view the situation that suppose ten wells were drilled simultaneously, and the probability

of blowout was one in 5,000 , then the probability of a blowout if ten were drilled would be quite -- would be much higher.

Q So that while the probability for each well drilled, the probability of a blowout for each well drilled is one in somewhere between one in a thousand, and one in 10,000, you should multiply by -- well, that figure should be multiplied according to the number of wells drilled at any given point to determine the probability.

A Yes.

Q In other words, if you're looking ahead and say to yourself, "we're going to drill ten instead of two," you would multiply this figure by ten. Am I doing this right?

A Yes, I think that's essentially correct. Also I've said earlier on, that if one assumes there's a higher probability in the beginning because of assumptions about lack of experience or maybe other assumptions we can make, then possibly the cumulative probability could be countered by increased experience. Again these are all assumptions.

Q Yes. Well no, I was just looking at the mathematical side of it. You made that point earlier on that the experience gained might offset the increase in probability owing to the greater numbers of wells drilled.

A Correct, yes.

Q Sorry, carry on, please.

A So just looking at the

environmental threat from a blowout at proposed 1976 drilling sites, that's just the second paragraph on page 23, it is unlikely that the oil discharged into the Beaufort Sea from a single oil well blowout running for several years would have any effect whatever on global or even local climate. Hence the main environmental threat is to the biota of the Beaufort Sea region. Both of the Canmar drilling sites are in the transition zone where winter ice is subject to movement of the order of kilometers per day, and where leads open, freeze over, and close throughout the winter in a manner which is not predictable in detail.

Canmar Site No. 1 is positioned in the transition zone where a blowout is comparatively most damaging to plant and animal life because of the likelihood of winter and spring pollution of the active leads north of the mainland fast ice.

Canmar Site No. 2 , this is further north, is located in the transition zone where a blowout is marginally less damaging to overwintering wildlife since much of the winter oil discharge will be dispersed under the ice, at least until spring.

For comparison, a scenario was developed for a hypothetical site No. 3 to reveal the effects of a blowout from a well drilled nearer shore where the ice is landfast in the winter. This scenario showed that a blowout is comparatively least damaging to overwintering marine mammals and spring migrants, assuming that burning at the blowout site is effective in the spring.

Drilling a relief well in 1977. The environmental threat ratings assume that the imaginary oil and gas blowout is controlled by drilling a relief well before October, 1977. This may not be possible since the 1977 ice year may be heavy and the subsequent open water season may be short. It is not possible usefully to predict the likelihood of light or heavy ice years. A blowout site can be continually ice-covered or ice-infested. This is more probable at Canmar Site No. 2 than at site No. 1, and less likely at the landfast site No. 3.

Considerations affecting the escape of oil into the environment. Available technology is severely limited in its capability of mitigating the threat to the environment arising from the loss of control of an offshore oil well, particularly in the Beaufort Sea transition zone. Unless a blowout were self-sealing, damage from released oil could only be prevented in one of three ways:

(a) The flow can be stopped by the drilling of a suitable relief well.

(b) The oil could be contained at or near the bottom.

(c) The oil could be contained or disposed of after it has reached the surface.

At present no technology exists for drilling a relief well in the Beaufort Sea transition zone except during the brief summer open water period. In some years no suitable open water period occurs.

There exists no technology

for containing the oil near the bottom, which is suitable for controlling escaping oil and gas in the Beaufort Sea transition zone.

Contamination and disposal of oil at the surface is possible under certain limited circumstances. However, existing --

MR. BAYLY: Contamination or containment?

A Containment, I'm sorry. I'll read that again.

Containment and disposal of oil at the surface is possible under certain limited circumstances. However, existing technology is known to fail in modest sea states and wind states such as occur for 55 to 60% of the time during the summer in the Beaufort Sea. According to scenarios developed in the Beaufort Sea project, existing technology is unlikely to be successful in disposing of a large fraction of the oil which escapes during the winter period of moving ice.

The environmental prediction system which will be in place in the Beaufort Sea during 1976 and 1977 will not be sufficiently complete to permit prediction of the movement of escaped oil as accurate as is allowed by the state of the art. Thus the deployment of devices such as booms for the protection of especially vulnerable areas will be less efficient than is technologically possible.

Oil spill counter-measures in 1977. When I say "Oil spill counter-measures" I

am really referring to surface -- oil that is now on the surface or under the ice.

Canmar has endeavored to assemble equipment and develop methods to mitigate damage of oil pollution from a blowout. However, the harsh Arctic conditions place severe constraints on the effectiveness of cleanup activities in 1976. New technologies adapted to Arctic marine waters are in embryonic stages of development. As a consequence of an imaginary blowout on the 5th of October, 1976, and assuming a standard blowout (based on information received from the industry) in which the initial flow is 2,500 barrels per day, reducing in a month to 1,500 a day, and then continuing at that rate until the well is brought under control, it is concluded that:

- Most of the oil discharged from October, 1976 to early July, that is the summer of the following year in '77, will escape containment and disposal at both Canmar sites. Approximately 25,000 cubic meters of oil will be mixed with the ice and water of the transition zone. Spring burning will only have limited success. Spring burning of the oil might, on the other hand, be very effective for a blowout occurring on landfast ice regions.

- 55 to 60% of the 21,000 cubic meters of oil discharged from July '77 to October '77, that is during the open water period of the subsequent year, and the assumed month of well control, would be likely to escape containment and disposal at either Canmar site. That is the bulk of it would likely escape containment.

Of the total amount of oil blown by winds towards the coast lines, inshore oil spill counter-measures are unlikely to eliminate more than 5%. On the other hand, where protection of specific bays and lagoons is sought, counter-measures would be effective for at least 45% of the summer.

- Oil spill counter-measures proposed for 1977 are not likely to decrease significantly the estimates of environmental impact of an oil and gas blowout occurring at either Canmar site.

This is the last summing up. The threats of a blowout to the Arctic marine food chain. An autumn oil well blowout at either Canmar site, but more so from site No. 1, just north of the landfast ice zone, could pollute active leads and open water in the ice of the transition zone through the winter and spring. Assuming the blowout is controlled within one year, the oiling of these active leads vital to the survival of marine mammals and birds will be short-lived. By the winter of 1977-78 the oil will have been dispersed northward into the Beaufort Gyre and southward to the inshore waters and coastlines.

- It is predicted that primary production will be inhibited where oil collects in the ice of the transition zone so that a localized depletion of fish stocks, invertebrates and sub-ice algae will occur. This depletion will have significance if it occurred in the main east-west leads used for migration and in zones of active shearing used by resident seal

populations. Seals, whales, and some marine fishes and birds depend on the spring influx of food to recover from a winter's fast, a migration or an annual moult.

- The predicted mortality of overwintering ringed and bearded seals concentrated in the ice of the transition zone is not known. However, it is certain that a large fraction of the sub-adult and adolescent seal populations, perhaps 30% or more, in the south-eastern Beaufort Sea will encounter oil.

- The predicted contamination of offshore leads for at least one spring season and more chronic long-lived pollution of the coastal bays and shorelines will have the greatest impact on the bird life of the south-eastern Beaufort Sea.

- Coastal fishes comprise other wildlife populations sensitive to oil pollution. The recovery from an initial fish kill is predicted to be slow, perhaps a decade, a result of the persistent toxicity of oil in lagoon and embayment sediments.

It is evident that the effects of an oil blowout could be severe on some portions of the ecology and on some populations, particularly sea birds. However, none of these effects is likely to be irreversible, although recovery might take as long as a decade in some cases. Except for birds, the economic values of marine wildlife resources threatened is of the order of tens of thousands of dollars per annum which is very small compared with the magnitude of the investment in the oil industry. Various estimates have been made of the economic values of migratory

birds as a renewable continental resource, in the order of millions of dollars per annum. The economic valuations of birds are exceedingly difficult to make on a sound basis, but the birds are visible throughout the continental flyways and are a substantial recreational resource, having a high social and indirectly a high economic value. Even so, the importance of these consequences will have to be judged on largely sociological and environmental grounds, not economic ones.

That ends the testimony.

MR. BAYLY: Mr. Commissioner, this panel is now available for cross-examination.

(QUALIFICATIONS & EVIDENCE OF J. SHEARER MARKED EXHIBIT 466)

(QUALIFICATIONS & EVIDENCE OF C.P. LEWIS MARKED EXHIBIT 467)

(QUALIFICATIONS & EVIDENCE OF A.R. MILNE MARKED EXHIBIT 468)

MR. GOUDGE: I take it, sir, that Mr. Bayly would prefer us to go through the batting order in relation to Mr. Milne, if possible. I canvassed counsel and I think it's probably unlikely we could finish him today, but --

MR. BAYLY: If that is possible I think it's perhaps worth a try anyway, Mr. Commissioner. If not, I've discussed it with Mr. Milne and we can bring him back, but probably not until late Monday of next week.

MR.GOUDGE: Perhaps then, sir,

I could suggest that we begin by going through the batting order as far as Mr. Milne is concerned, except for Mr. Veale. When we reach him, since he is only going to be here today, I'd suggest that he be permitted to ask all his questions of all three panelists.

THE COMMISSIONER: Right.

MR. MARSHALL: My understanding is that I'm next to last in the batting order. If Mr. Veale would like to start, perhaps that would be the most sensible thing, sir.

THE COMMISSIONER: I think so.

CROSS-EXAMINATION BY MR. VEALE:

Q Dr. Milne, I understand your basic submission is there are substantial environmental risks with offshore drilling in the Beaufort Sea, and my question is: Are there any other areas in the world where the risk that you speak of is as substantial as it is in the Beaufort Sea?

WITNESS MILNE: In terms of environmental risk I really have to respond as to what are major differences and why one might surmise there is more of an environmental risk in the Beaufort Sea. If we -- and I think it's fair to say that the probability of a blowout depends partly on the competency of the technical system and also on the people who operate it, and it's very hard to differentiate between that in the Beaufort Sea compared to elsewhere.

So on that basis we can assume we start off on square one in every area offshore. So what are the major differences in potential/for environmental impact? Those primarily appear to be concerned with the time during which a blowout has to be allowed to remain running out of control. Since there is a very short drilling season in the Beaufort Sea, sometimes virtually none, depending on the site, and at most perhaps four months in a good ice year, this means that for the remaining eight months of the year there is no means of drilling a relief well or bringing it under control. So one is left with ten months or more of a free-running oil well blowout, and that's the No. 1 difference, because elsewhere in the world it is possible to do something about it, even though it may be difficult, at least there is a good possibility of getting back during wintertime elsewhere offshore.

The No. 2 problem is the higher life forms -- the mammals, the whales and the sea birds -- want to occupy the same leads that the oil will occupy. So there isn't the possibility of the dispersal of the wildlife in the Beaufort Sea as there is elsewhere. Also because of the concentration of open water along the shores, and the likelihood of oil getting inshore, they coincide again with where the wildlife like to be. It's just where oil is, that's where the wildlife is likely to be, more so than in other parts of the world.

Q And I take it that if you made a comparison of the Beaufort Sea with the

Arctic Islands offshore drilling, for example, there are also substantial differences in the ice conditions, which would make the risk greater in the Beaufort Sea than in the Arctic Islands.

A With regard to systems which already have drilling authority in the archipelago, these offshore ones have been on shorefast ice and have been placed on thickened or built up pads of ice, and since I believe that these are the offshore ones are primarily gas wells, and the subsequent ones are delineation gas wells, the situation has only been permitted to go on if there is left time in the season to drill a relief well from another ice pad. So it means the construction of two pads and the possibility of getting in there and doing something about it. So in the archipelago we're looking at quite a different situation than in the moving ice of the transition zone using floating drill ships working in the open water season, whereas in the archipelago they're operating from landfast ice during the late winter-early spring.

Q So it's then the condition of the moving ice which can be isolated as the major distinction then between those two regions.

A Distinction both on season, of operation, and whether it's in fast ice or moving ice.

Q And is there also a distinction on age of ice?

A Not necessarily in the

transition zone in describing the age of the ice, which is in motion depends on the season. Sometimes it's comprised of ice that has grown in one season and other times is comprised of high percentages of older thicker fresher ice.

Q Now I take it also that in the Arctic Islands there has been drilling taking place during the winter period -- the winter season -- as well as the summer season.

A Offshore in the Arctic Islands in my knowledge -- to my knowledge the only offshore drilling has occurred in the winter and spring from ice thickened pads built up in the shorefast and landfast ice from a stable motionless platform for practical purposes.

Q And that type of drilling cannot take place in the Beaufort Sea area.

A That's true. The only equivalency we have there is from the artificial islands which are again in very shallow water and are year- round operations. That's the only thing anywhere near that has any similarity whatsoever.

Q Now, you've --

THE COMMISSIONER: And you said that in the Arctic Islands they are obliged to cease drilling in any season while there's still time to drill a relief well.

A Yes, there is provision -- also these wells, I understand, are limited in depth to permit a relief well to be drilled before

the season ends, or before the landfast ice breaks up.

THE COMMISSIONER: Fine.

MR. VEALE: Q Dr. Milne, you've also spoken about the --

THE COMMISSIONER: Excuse me. In the Beaufort Sea, that kind of provision would exclude open water drilling in the summer completely.

A Not necessarily. I think it would probably be a lot less economic, but there are two -- a minimum of two drilling systems going in and I think it is possible to devise, you know, as an amateur myself, to devise in the absence of good engineering information, a scheme whereby a relief well could be done, but it would be -- the shorter the drilling season then the less viable the proposition becomes from an industrial point of view, because one would have to terminate operations early enough in the season to permit a relief well, the continuation of a companion well which would act as a relief well, and this would occupy a large fraction of the season that would be left.

THE COMMISSIONER: Yes.

MR. VEALE: Q Dr. Milne, you also spoke about the length of time for recuperation of wildlife and fish stocks, and with respect to fish stock you had mentioned that recuperation could take up to a decade. Now, does that assume that there would be no fishing of that particular fish stock in order for that recuperation to take place?

A First, I'm not a biologist

-- my field is physics and geophysics, so I can't speak with any authority on this matter. But in our exploration of, during the production of the assessment Brian Smiley, who was the co-author , is a biologist and consulted with the fisheries people on the project who were on this panel the other day, and we endeavored to extract from these people their considered guesses as to what they thought. We attempted to pin them to the wall as hard as possible to come up with guesses as to what they thought might happen, and the results are displayed in the document or in the testimony.

Q Well, I may be pursuing an area where you don't wish to answer, but if we take, you know, that the whales and the seals and that type of animal, it seemed to me to be patently obvious that if there were great hunting in the recuperation period, it would obviously have a greater delay in terms of the recuperation that you're anticipating.

A Yes, I believe what you're alluding to is the fact that if there is already stressed biological systems, either from natural causes or from hunting pressure, each additional stress is bound to reduce the viability of that population. I don't think I can go very much beyond that in response to what you said.

Q But when you talk about burning off oil in the cleanup process, you spoke of the month of May. Now, does that create problems for the, environmental problems, in the burnoff at that particular time of year?

A Gee, in the actual buring off operation itself, I wouldn't think that that would be very significant. It would probably have a very marginal side benefit of keeping some of the birds away from the immediate area that was being burned off; but other than that I can't envisage any environmental damage caused by an offshore burning operation on the sea ice, of oil that is emerging at its surface.

Q Would you agree that it's a difficult season in which to conduct the actual operation because of flying problems relating to weather particularly?

A Yes, it is difficult, not just the operation itself but the logistics support which would be required to have significant effectiveness. You know, if you had good weather, then I believe you would need -- this is directly from Canmar -- you would need some 40 helicopters and you would have to have fuel shipped up from the south, 100,000 barrels of fuel to -- for the helicopters to use. You would have to deploy some 40-odd people in order to man the helicopters and do the burnoff operation. Now when you add those logistic problems to what I consider to be the effectiveness of doing it, and which involves the location of where the oil is and it's scattered all over the place. I really think it's a marginally effective operation, as far as environmental impact is concerned . Supposing you burn off 50% of it, get rid of that, you're still

left with that margin that is left when the weather is bad. So from an environmental impact significance I really don't believe it would -- this is certainly not effective, in my opinion.

Q Thank you, Dr. Milne.
Mr. Lewis, I understand, my understanding of your evidence is that the onshore facilities required to support drilling and so on offshore in the Beaufort Sea is the greatest problem, particularly concerning, for example, the possible harbor that would be constructed along the North Coast of the Yukon Territory. Is that correct?

WITNESS LEWIS: Well, speaking I think, both of the facilities associated with drilling of wells and with the facilities associated with production from the wells in the sense of pipelines, feeder lines from offshore, processing plants onshore, and further lines from there into the trunk pipeline.

Q Well, dealing specifically with Babbage Bight, I understand from your previous evidence that there is a -- that is the proposed site of a harbor, and I understand that it is the best site for the particular water depth that is required. You indicated this morning in your evidence that there were some difficulties with / Babbage Bight as a site. Would you elaborate on that?

A To my knowledge I don't know that Babbage Bite is a proposed site. It is a site whose feasibility as a port has been investigated by the Federal Department of Public Works in a study

which also examined other sites. For example Herschel Island, and the conclusion of that feasibility study was that the only possible location for a deep water port along the Beaufort sea coast was Babbage Bight, and I believe by "deep water port" they meant a port in which vessels with draughts up to 76 feet could enter.

Now with respect to the question there is no doubt that Babbage Bight has by far the steepest offshore gradient of any location along the Beaufort Sea coast, so ships could get in. But as I said this morning, it is a rapidly retreating vertical cliff coastline with large amounts of massive ground ice in it with rapid slumping, with these ground ice slumps that I talked about melting back, and so any facilities associated with the harbour which were on land would come into contact with a very sensitive area.

Q I also understand that at some time or other -- I don't know whether this was a proposal or just a feasibility study -- but the gas producer (and I think it was Imperial Oil) was considering the location -- considering locating a concrete aggregate plant at that particular site to support the offshore drilling that they might conduct. Are you aware of that particular proposal, whatever the status of it is?

A I'm aware of it to the extent that about a year ago a document was sent to me from the Department of Indian Affairs to review a proposal that Imperial Oil had submitted. I don't know

exactly what kind of proposal it was, whether -- I don't believe it was actually an application; but I was asked to review a proposal for the establishment of a shallow water harbour. I think they were concerned with vessels whose draughts would be up to 16 feet, for the establishment also of a concrete aggregate plant, of an airstrip big enough to land Hercules aircraft on, and a road extending from Babbage Bight to the mountains south-west about 30 miles from Babbage Bight where they would mine the material, bring it to the aggregate plant, and in combination with material available locally around the aggregate plant to make large blocks to use on artificial islands.

Q Well, without getting into a discussion of cumulative impact of having a harbor and say the plant established there, from your discipline is there any difficulty with establishing a concrete aggregate plant at that site?

A I think yes, and for very similar reasons to the problems of port. There have been -- I've already talked about the actual coastline itself behind the coast in the area where they're talking about having the plant and the strip and the road. I have looked at logs of seismic shock wells drilled in the area, and from those logs which I must admit,and I think everyone knows are notoriously unreliable, but from those logs it appears as if that entire area is underlain by a large amount of massive ice. I think probably as much massive ice as you would find anywhere along the whole Beaufort

Sea coast.

Q And that, I take it, means a certain degree of instability.

A That means problems.

MR. VEALE: I see. I have no further questions, Mr. Commissioner.

CROSS-EXAMINATION BY MR. EVANS:

Q Mr. Milne, I'd like to refer you to the paper you delivered to the Canadian Society of Petroleum Geologists, I believe at Calgary, the 2nd of October, 1974, entitled:

"Beaufort Sea and Mackenzie River Delta Environmental Studies."

In that paper you made a statement that,

"The Beaufort Sea project is a crash catch-up program which cannot by itself provide full and detailed information on this remote, hostile, ecologically sensitive region."

Now, I wondered what kind of -- from your experience as manager of the Beaufort Sea project, what kind of project do you think would provide adequate information? What kind of a continuing research project?

WITNESS MILNE: All right, what I believe you're asking is what kind of a project would -- how many years could we go on and provide a significant addition to the information we already have? Is that --

Q Yes.

A I think maybe I should

just review very quickly the content of the Technical Reports which will be coming out from the Beaufort Sea project. Incidentally, there are some 15 of these which will shortly be available. Some are immediately available, about six. Most of the -- in fact all of the major investigators have been government scientists for a number of years, and almost all of them have worked in the Arctic for a good many years, some for as much as 20 years, and it is clear that there has been a great in-gathering of pertinent information applicable to the Beaufort Sea which will emerge from the Technical Reports in the Beaufort Sea project, and which I believe there has been summarized with reasonable accuracy in the preliminary assessment. So what does that leave us with? It leaves us with as much as 20 years of back thoughts, considerations and data which has provided -- will be provided by the time the project is completed. So to add a significant amount of data to what has already been divulged or will be divulged at the end of the project, really has to be looked at in terms of the revelations or the revealing of gaps and what can be done with regard to those.

For example, do the -- does the beluga population consist of two separate populations, one that comes from the east and one that comes from the west? This would obviously have significance on future offshore activities in understanding what the impact might be. It is evident also that there is little knowledge of offshore fisheries in the Beaufort Sea simply because over all this long period of time

the direction in which the fisheries operations and research people have been conducting themselves hasn't been toward determining what these populations are. Instead they've been doing largely what was logistically possible, so here is another area where not many years of work, say several years of work would add a significant body of data to what is already known.

I think I'll just leave it at that and maybe you would like to enlarge on it with other questions.

Q The point that I'm trying to make is a very simple one, and that is until your project we knew almost nothing about the Beaufort Sea and we still really know comparatively very little, and would you agree that much more research is necessary in order to provide sufficient baseline data in order to deal with the area effectively. Would you agree with that statem ent?

A I agree that in certain areas there is a lot more work which would render you know, the kind of -- I think the essential problem in the Beaufort Sea is the recovery period of the wildlife populations following some kind of stress, like an oil well blowout, and if one can add some more precision to this period assumed for ecological cover, recovery, well here is where the research should be concentrated. On matters connected with bottom scouring, with sub-sea permafrost, with the knowledge of the sea ice cover and its motions, I think for the purposes of assessing environmental impact and the

precision with which it could be done, these studies were probably adequate for the purpose at this time.

Q Now, on page 23 of your prepared evidence that you've given today, you stated

"It is unlikely that oil discharged into the Beaufort Sea from a single oil well blowout running for several years would have any effect whatever on global or even local climate."

In that same paper that I referred you to earlier you discussed the quite possible climatic effects and at that time you seemed to draw a somewhat different conclusion. You stated in part,

"If large areas were affected, the ice cover could irreversibly disappear, resulting in a serious alteration in the world's climate, perhaps even a new Ice Age."

I wonder if you'd like to comment on that? Did some things --

THE COMMISSIONER: Who said that?

MR. EVANS: Mr. Milne said that in a paper that he delivered in October of 1974.

THE COMMISSIONER: That's the petroleum --

MR. EVANS: That's correct. I just wondered if you appear to have changed your idea, your feelings somewhat, and I wondered if this was due to some information you gained through your research project?

A I think in that paper I

referred to or alluded to that it was the opinion that this was a possibility, and I think that's how it went. I've forgotten the exact words. This was a worldwide concern, and the background there is there had been several papers in the literature referring to this possibility and that had to be responded to.

Q Yes, you refer --

A That's the essence of it.

THE COMMISSIONER: You had to consider that in your study.

A Yes, that was a consideration. All right, what is the situation now and how did I arrive at this wild statement?

MR. EVANS: Q Perhaps I can add to that, Mr. Milne. You referred to a paper by Campbell & Martin where they alluded to this possibility, and then a rebuttal by, I believe, Ayers, Johns & Glaeser.

A Glaeser.

Q I wondered if you could, you know, comment on how your project handled this question and how you drew your conclusions as stated today?

A If I just go back to the Campbell & Martin paper, there were a number of assumptions made in that paper based on -- well, on the lack of knowledge of ice in the Beaufort Sea and how oil, particularly with regard to how oil would interact with sea ice. In the Beaufort Sea project we

undertook to do a number of experiments to try to ascertain just what would be the actual interaction as much as possible of oil in sea ice. Now, the Campbell & Martin paper really referred to a proposition that the oil, once it got in the polar pack ice, or under the polar ice, would take several years to emerge on the surface and therefore it would in a sense be encapsulated or preserved as it circulated in the Arctic Ocean. It also made certain assumptions about how it would spread, but it did not deal with the problem of biological decay of the oil or with its eventual chemical fate or biological fate, if you like. It also made assumptions about spreading of a certain amount of oil with regard to -- well, how much area it would cover, and therefore how much area it would influence. Would it be a monomonecular layer of oil, or would it have some, be concentrated by the sea ice itself and therefore only cover a very small area? So all these factors were of importance to investigate and these had been investigated to a large extent, where possible, in the Beaufort Sea project with the exception of actually contaminating offshore areas with oil, and from these studies it has been pretty clear that for a blowout running for one or two years from one well, that the amount of oil and its ultimate fate would have relatively little significance as far as the depletion of the percentage of the ice cover in the Beaufort Sea relative to the depletion which is caused by natural climatic variations. In other words, you see big open areas in which are

far, far more significant in affecting climate than would be a small area depleted or decayed by having incorporated oil.

THE COMMISSIONER: The sheer physical volume of oil is insufficient when its dispersal is not widespread enough to make a difference.

A Yes, it's also coupled with the fact, "Well, what is its ultimate fate from its pristine form when it emerges out of the well to what it ultimately might become after a while." So one situation says it's untrapped in the ice and therefore it emerges and is spread very thinly; in actual fact in my opinion -- not fact, but my opinion the oil will emerge to the surface almost entirely in the first year. In the following summer it will be subject to atmospheric effects, evaporation, decay, concentration and the tar balls, some of which will be -- have a specific gravity greater than water and could sink to the bottom, and therefore in a climatic -- from a climatic point of view would not likely have much effect in the following years on you know, the accumulative effect would disappear rather rapidly. This is not to discount the possible climatic effects which might occur from a continuation of oil spills which might result from more wells being drilled and offshore production, and production spills and pipeline breaks. Now we're getting into a different order of magnitude there and --

Q Precisely, and that in a sense is the difference between the risk entailed

in the drilling of these two exploration wells and the risk that we might face, given a proliferation of exploration and production activity in the delta and the Beaufort Sea. Do you remember, Dr. Milne, that when the Prime Minister introduced the Arctic Waters Pollution Prevention Act in the House of Commons prior to the voyage of the "Manhattan" he referred to the possibility that an oil spill in Arctic waters might make -- might have some effect on the earth's climate and no doubt in saying that he was advised that the vast quantities of oil that would be spilled if a tanker sunk in the Arctic would cause that impact. Is the amount of oil you would be -- in a tanker the size of the "Manhattan", and we appreciate that the knowledge of these matters was probably more limited when he spoke six years ago than it is today, but is the volume of oil in a tanker greater than what you would get issuing from a well for one year or two years, or might that statement have been made on the assumption that a tanker would sink in different waters? Do you have any comment on that?

A I recall again from memory that a blowout running for a year is about -- somebody could correct me on this -- I believe about a third of a super tanker, and so we're dealing with sort of the same order of magnitude of a spill, but I might also comment that one of the studies of the project also considers long-term effects and speculates on how much oil might be spilled and what might happen to it. It also concludes as well on a pessimistic note

that the state of knowledge of climatology is such that one is not in a position to come up with an answer, which is sort of a negative result.

Q Mr. Evans asked you about the Beaufort Sea study project, and put to you the words you used when you made that speech,

"Crash catchup,"

and your colleagues, Dr. Grainger and those on his panel made it plain that they felt that our knowledge of the Beaufort Sea is by no means complete as a result of this study; but you, it seems to me, are satisfied that the study has enabled you to assess the risk so far as it can be assessed, of a blowout occurring if these two wells were drilled this summer, and you've outlined in great detail the likely environmental damage that you feel would occur if the wells -- if there were a blowout at one of these wells.

It appears to me, just having listened to all of you, that while you don't know all that there is to know about the Beaufort Sea, you have made a determination that there is a risk entailed in drilling these wells and that if there is a blowout, damage will occur, damage which you have described as widespread, and it will last a considerable length of time. You're not doing a report on the Beaufort Sea; you're doing a report on the possible impact of an oil spill, and while you may not have succeeded in the first endeavor, that wasn't what you were asked to do and you appear, as I understand your evidence, to feel you succeeded in

the latter endeavor. You don't know all the likely impacts that oil will have on these marine organisms, on the food chains, and even on the large mammals in the sea, but you certainly appear to have gone a long way toward adumbrating the consequences in a way that enables the politicians who have to make these decisions to decide whether the risk is acceptable or unacceptable. Do you care to comment on that observation of mine, because it's certainly my impression from what your colleagues and you have said, that you have gone that far.

A Yes. While you have been saying that I've been thinking about a response, and one of them goes something like this, that there are many pathways in a narrative or a scenario that one can take, and the precision with which a story can be -- that a story might relate to reality is, you know, you might never find out and --

Q You hope not to.

A -- you hope not to find out. More research may reveal that the impact might be higher, or it might reveal that the impact may be lower. I think we tend to err on the pessimistic side and therefore the impact might be less, I really don't know; but as we get further down in the food chain in the more elementary parts of the food chain, the more difficulty it is to say anything with precision and it is possible with more work to render those estimates to be more precise. I don't know whether I can say much more about it, than that at

the moment.

Q Well, at any rate you said in your preliminary remarks that so far as the oceanography of the Beaufort Sea and the movement of the sea ice and the conditions of the sea and the ice itself, the way they bear on your assessment of the risk and the consequences, you were in a position to know an awful lot about those factors, and they appear to be in many respects the most important factors because they limit the drilling of a relief well, which you said is the principal concern, so far as stopping the thing is concerned, and they also enable you to discuss the open water, the leads forming in the spring which -- to which the oil is drawn just like the birds and the -- well, at least the whales and the seals and well, the birds as well. So that in those areas you appear to have pinned this thing down so far as it is likely ever to be pinned down.

A If you don't mind, sir, I'd like to make one comment which I think if one doesn't know very much about an area it can over-simplify the various paths or come up with one most likely path and description of a scenario. In the case of surface currents, for example, in the Southern Beaufort Sea, it would be very nice to be able to predict ahead of time, months ahead of time what the surface currents are likely to be in the Southern Beaufort Sea. However, from past data one simply has an arrow on a map and that's, you know, that's as much precision as you're going to get. The more

meaaurements that are done, the more we realize that there are various other influences which increase in number with the more measurements you make, and therefore what is being revealed is a higher degree of randomness than before. This may also occur with wildlife studies which says that one year is completely different from the next, and each subsequent year you make measurements that's different from a previous one. So one only can devise some mental concept of a median or an average which is never precisely likely to be reality.

THE COMMISSIONER: Well, it's a difficult business.

MR. GOUDGE: I wonder if this would be an appropriate time to stop?

THE COMMISSIONER: I think that I have some more questions or at least musings on which I should like Dr. Milne to comment, and I know Mr. Evans has more questions. Mr. Goudge has some, and if it's -- if we can impose on Dr. Milne's good nature to return on Monday, this is important certainly to us and we would appreciate that. I --

MR. GOUDGE: If not Monday, perhaps Tuesday.

THE COMMISSIONER: Yes, whenever it is possible. It would be helpful if it were next week if you could come.

MR. BAYLY: I have spoken to Mr. Milne and it appears as though it may be possible and we can discuss the logistics of that and see what

can be done.

THE COMMISSIONER: I wonder, Dr. Milne, if you would -- Dr. Pimlott gave evidence here a couple of weeks ago and he had some figures on the experience of spills in the Gulf of Alaska and other places of temperate waters, or at least not the Beaufort Sea. You might, if you don't mind, just reading over his paper on the plane going down to Yellowknife or coming back here next week and comment, if you wish, if you don't wish to that's your business, but comment if you wish on the matters you've raised regarding the probability of a spill, and anything else in his paper relating to these issues. I don't want your views on how the government makes decisions.

MR. BAYLY: I understand from Dr. Pimlott that those statistics came out in cross-examination but I'd be happy to get them together and perhaps --

THE COMMISSIONER: They came from where?

MR. BAYLY: They came out of cross-examination, and we don't have a transcript.

MR. GOUDGE: They are contained, I think, in a volume which was filed as an exhibit which we can perhaps dig out at the end of today and give to Dr. Milne.

THE COMMISSIONER: Well, they'd be in here, wouldn't they?

MR. BAYLY: We haven't got that far yet, sir.

MR. GOUDGE: We haven't got that volume yet, sir.

THE COMMISSIONER: Oh.

MR. GOUDGE: But we can provide --

THE COMMISSIONER: Well, you know what I'm thinking of.

MR. GOUDGE: -- yes, we can provide Dr. Milne with the statistics.

THE COMMISSIONER: At any rate you might comment on those when you return, if you wouldn't mind, and as I say, anything else in Dr. Pimlott's statement which Mr. Bayly will give you that you might wish to comment on where he may have taken a point of view that's at variance with what you concluded. I'd like to know that.

A Very good, sir.

THE COMMISSIONER: So we'll --

MR. GOUDGE: Adjourn till ten o'clock tomorrow morning?

THE COMMISSIONER: -- adjourn till ten o'clock tomorrow morning.

MR. BAYLY: I would propose, if there are no objections, that cross-examination of the other two members of this panel continue tomorrow morning, and that we call Mr. Snow and Mr. Pettigrew following that.

THE COMMISSIONER: Fine.

(WITNESS MILNE ASIDE)

(PROCEEDINGS ADJOURNED TO FEBRUARY 14, 1976)

MACKENZIE VALLEY PIPELINE INQUIRY

IN THE MATTER OF APPLICATIONS BY EACH OF
(a) CANADIAN ARCTIC GAS PIPELINE LIMITED FOR A RIGHT-OF-WAY THAT MIGHT BE GRANTED ACROSS CROWN LANDS WITHIN THE YUKON TERRITORY AND THE NORTHWEST TERRITORIES; AND
(b) FOOTHILLS PIPE LINES LTD. FOR A RIGHT-OF-WAY THAT MIGHT BE GRANTED ACROSS CROWN LANDS WITHIN THE NORTHWEST TERRITORIES,
FOR THE PURPOSE OF A PROPOSED MACKENZIE VALLEY PIPELINE

and

IN THE MATTER OF THE SOCIAL, ENVIRONMENTAL AND ECONOMIC IMPACT REGIONALLY OF THE CONSTRUCTION, OPERATION AND SUBSEQUENT ABANDONMENT OF THE ABOVE PROPOSED PIPELINE

(Before the Honourable Mr. Justice Berger, Commissioner)

Inuvik, N.W.T.

February 14, 1976

PROCEEDINGS AT INQUIRY

Volume 125

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E R R A T A

By N.J. Wilimovsky :

VOL. 109, p. 16595,	line 6	in = and
	8	a = of
	19	in = and
16691	22	dimensionalist = dimensionless
16692	15	I have = I may have
	22	coincided = established
16693	6	imperical = emperical
	22	vital (delete)
16699	19	Elverson = Alverson

APPEARANCES:

Mr. Ian G. Scott, Q.C., Mr. Stephen T. Goudge, Mr. Alick Ryder and Mr. Ian Roland	for Mackenzie Valley Pipeline Inquiry;
Mr. Pierre Genest, Q.C., Mr. Jack Marshall, and Mr. Darryl Carter	for Canadian Arctic Gas Pipeline Limited;
Mr. Reginald Gibbs, Q.C., Mr. Alan Hollingworth & Mr. John W. Lutes,	for Foothills Pipe Lines Ltd.;
Mr. Russell Anthony & Pro. Alastair Lucas Mr. Garth Evans	for Canadian Arctic Resources Committee;
Mr. Glen W. Bell and Mr. Gerry Sutton,	for Northwest Territories Indian Brotherhood, and Metis Association of the Northwest Territories;
Mr. John Bayly or Miss Leslie Lane	for Inuit Tapirisat of Canada, and The Committee for Original Peoples Entitlement;
Mr. Ron Veale and Mr. Allen Lueck	for The Council for the Yukon Indians;
Mr. Carson H. Templeton,	for Environment Protection Board;
Mr. David Reesor	for Northwest Territories Association of Municipalities;
Mr. Murray Sigler	for Northwest Territories Chamber of Commerce.
Mr. John Ballem, Q.C.,	for Producer Companys;

INDEX | Page

WITNESSES FOR C.O.P.E.:

EXHIBITS:

Inuvik, N.W.T.
February 14, 1976.

(PROCEEDINGS RESUMED AT 10:10 A.M.)

THE COMMISSIONER: Well, we'll come to order, ladies and gentlemen.

MR. EVANS: Mr. Commissioner, I believe I was questioning this panel when we left off yesterday.

THE COMMISSIONER: Right. Well proceed then.

MR. EVANS: I'll continue with these two gentlemen on the understanding that I can question Mr. Milne on Wednesday when he returns.

THE COMMISSIONER: Right.

JAMES SHEARER,
CHARLES PETER LEWIS, resumed:

CROSS-EXAMINATION BY MR. EVANS (CONTINUED):

Q Thank you. Mr. Lewis, assuming that a future scenario in which somewhere between 200 and 300 wells are drilled in the Beaufort Sea, what do you think the likelihood would be of a well going out of control?

WITNESS LEWIS: I really have no idea.

Q You couldn't comment on that?

A It's not within my field of expertise at all and any comments I would make --

Q Mr. Milne is better qualified to answer. Do you have anything to say about that, Mr. Shearer?

WITNESS SHEARER: Not really.

THE COMMISSIONER: Next question.

MR. EVANS: With respect to an area that I think is within your area of expertise, what clean-up measures do you think are possible once an oil spill hits the beachs, like specifically around the Mackenzie Delta and Beaufort Sea area?

WITNESS LEWIS: I think the general consensus among the people involved in the Beaufort Sea project, at least, and I think this would include the industry is that once the oil gets on the beaches or on the low-lying parts of the river deltas, that any clean-up measures would do more damage than leaving the oil there. So, I would suggest that the policy, the suggested policy, will probably be to leave it.

Q O.K. Now, with respect to flowlines which, I understand, are the lines that are going to lead the gas and oil onshore; would there be a problem with buried flowlines near the coast when-- you know, for instance when the coast is retreating?

A I think there could be great problems with buried flowlines near coasts. Specifically, most importantly near cliffed areas where there is a large amount of ground ice which are rapidly retreating which, in some cases, have ground ice which extends below sea level and out underneath the nearshore area, so you would effectively be putting your pipeline through, degrading massive ice in the nearshore area and into massive ice at the shoreline. That problem, the coastal retreat problem of course, would not be so

significant in the depositional area, depending on depth of burial, which, I assume, would be deep enough that no normal storm event could expose the pipelines so you'd have a much less serious situation there.

Q By "problem" I take you to mean the possibility of a break in the line, is that correct?

A The possibility of exposure of the pipe and to ice, for example, moving in the near-shore area or to any other two-way forces which might undermine the pipe. This would be, I think, most serious where the shoreline is cliffed and rapidly retreating; most dangerous.

Q I see. Well, how deep would this have to be buried in order to have some element of safety?

A Well, again, that would depend upon which type of coastal land form you were bringing the pipe into. In theory of course, the waves are capable of eroding to a depth of about ten meters. This is a -- when I mentioned that ten meters, or thirty feet, approximately yesterday, I said it was a generally accepted level. Within the Beaufort Sea, it seems to have some meaning because we find that evidence of ice scouring decreases to almost zero shoreward of the ten meter line, indicating possibly two things. One, that not as many scours are occurring because we are within the landfast ice zone and, two, that the waves are capable of moving the sediment in that area and of infilling scours. Perhaps there's a third as well.

The sediment in the nearshore area tends to be coarser and wouldn't maintain a scour as easily as the finer sediment offshore, so that's the maximum, that obviously to bury a pipeline thirty feet, coming into a depositional area might not be necessary but for reasonable safety, I think that would be a figure to work with.

Q Now, I've given you one of the exhibits which-- on which there's a route drawn. That's been referred to as the"Barry Route". Dr. Barry drew that for us the other day and he feels that's a better route than the one cross-delta route proposed by the company. I wonder if you could comment on it.

A Well, as I said in my evidence in chief, I would certainly favor not crossing the delta at all. Now, as opposed to a choice between the route which CAGPL proposes and the route which Dr. Barry proposes, on the basis of geomorphological ground alone I don't think that there's really much to choose between the two and I know that Mr. Barry's work -- or suggested route -- is based on biological considerations and then, given those considerations, his route is probably the better route but not for geomorphological reasons.

Q Yes, Mr. Lewis I was asking you just to comment from a geological point of view.

A O.K.

Q Now, Mr. Shearer, will the process of subsea pingo formation cause movement of the ground under the flowlines? I think you discussed pingos quite extensively in your paper.

WITNESS SHEARER: As I understand the question, are you asking me if subsea pingo formation will move flowlines that have already been installed in the area?

Q Yes, and after that to what degree that's likely to be a problem?

A I would think that they probably don't. I would think that most of them that are going to form have formed by now. Their process of formation is the replacement of the freshwater lakes. They used to be by saltwater some five thousand years ago and I think that they've formed to their maximum extent now, although there may be some movement, but I don't think there'll be any significant -- added significant numbers of new pingos forming at this point. So, I don't think that would be a problem.

Q Now, there's been quite a lot of discussion about shorefast ice but I at least don't have very much understanding of this subject. I wonder if you'd like to discuss shorefast ice in the Beaufort Sea, compare it with that in other areas, and talk about ~~its'~~ its potential to serve as a drilling platform.

A Well, I don't really know very much about it. I can make some comments, but they're not based upon a lot of personal research. I feel that in terms of a drilling platform, the shorefast ice in the Arctic islands is probably a better platform because they happen to be drilling in deeper water, therefore, they can -- the drilling platform can

absorb more lateral movement and the shorefast ice certainly moves when the weather changes. The ice contracts and expands so you get a certain lateral movement just due to expansion and contraction.

THE COMMISSIONER: Excuse me. You -- I understand what you've said, but you said it's better -- drilling there is better, better than what? What are you comparing it to, drilling from a drill ship, or?

A No, I'm sorry. I would say that using the landfast ice in the Arctic islands gives you one extra level of leverage, say using land-fast ice in the Beaufort Sea area.

Q Because of the depth?

A Because of the depth, you can absorb a greater depth range, right. I guess I don't want to add any more to that. I don't want to go too far away.

MR. EVANS; O.K., I don't have any further questions, Mr. Commissioner.

THE COMMISSIONER: Thank you Mr. Evans. What is the order, Mr. Goudge?

MR. GOUDGE: I think it would be Mr. Hollingworth next, sir.

MR. HOLLINGWORTH: I have no questions.

MR. GOUDGE: And then Mr. Marshall.

CROSS-EXAMINATION BY MR. MARSHALL:

Q I have a question. Mr.

Shearer. I was away when you gave your evidence before and perhaps had I been here we would have got this cleared up. Do I understand that you have produced the map that's on the wall there showing the delta and the Beaufort area, with rather a bad case of the measles, all those little speckles all over it?

A That's correct.

Q I was looking at that the other when somebody drew it to my attention. I see a heading, "Projected CAGSL Activity" in the legend, in the lower righthand corner.

A Can you give me a minute to go and have a look at it?

Q Sure.

A -- Refresh my memory.

Q It's about the oil pipeline under that heading. My point is simply this Mr. Shearer, isn't it clear that the heading is wrong. You're talking about projected activities by a wide variety of people, not by Arctic Gas?

A Of course, of course. Yes.

MR. MARSHALL: That's all I have to ask. The reason I asked was that Mr. Veale asked me the other day about all these facilities Arctic Gas was planning to build off in the Beaufort Sea. He thought it was one of the Arctic Gas maps that had been drawn so well.

MR. BAYLY: Perhaps Old Crow was in Alaska on it.

MR. MARSHALL: Foothills had

been left off, I think that was the distinguishing feature.

THE COMMISSIONER: It made it suspicious that Arctic Gas appeared to have prevailed.

MR. HOLLINGWORTH: I don't mind being left out of that activity.

THE COMMISSIONER: All right Mr. Goudge, any questions?

CROSS-EXAMINATION BY MR. GOUDGE:

Mr. Shearer, left me start with you. I take it there was a study done for the Beaufort Sea Project on bottom sediments in the Beaufort Sea.

A Correct.

Q That wasn't your study but you may have some knowledge of it.

A I should have some, yes.

Q Let me ask you in particular in relation to Shallow Bay whether you have any knowledge of the nature of the bottom sediments in Shallow Bay.

A I don't have any direct knowledge of the nature of sediments in Shallow Bay, except that I've done some work in the channels very close to Shallow Bay.

Q What does that work lead you to speculate at least about the bottom sediments in Shallow Bay?

A Well, that they would be very fined grained and I believe there's no deep channel running Shallow Bay. In other words, it's an

area where the narrow channels widen when they hit the sea and sediments deposited in it, it's quite shallow. I'm just referring to my memory of Canadian Arctic Gas -- gee, what's the man called -- their particular map running across Shallow Bay of the -- it's a particular map showing the pipeline route across Shallow Bay and they have the depths recorded there.

Q Yes. Let me ask you to give your view as to whether the sediments on the bottom of Shallow Bay would be loosely structured or compacted in any way?

A I couldn't answer. I really don't know whether the bottom of Shallow Bay is frozen or not and I would presume if isn't, there might be more compaction that if it -- according to what Peter said yesterday, that if it was frozen.

Q Well, Mr. Lewis, let me ask you the same set of questions. Do you have any knowledge of the nature of the sediments on the bottom of Shallow Bay?

WITNESS LEWIS: The only knowledge I have in addition to what Mr. Shearer's already mentioned, is a report of a set of drill holes that were done by Northern Engineering for CAGPL across Shallow Bay along the proposed route.

Q Have you seen those?

A I saw them just before I came up. I just had a chance to skim through. The--

Q What opinion --

A They were just logs

giving the gross characteristics of the sediment primarily silts, some find sands and one other very interesting point and that is in a couple of the holes offshore, in Shallow Bay, frozen ground at depths below the bottom in the order of twenty to fourty feet, so unfrozen above that; some unknown thickness of frozen ground below.

Q How frequent were the finds of frozen ground?

A I didn't have a chance to go through it in any detail to know if it was continuous or not. Just that it had been found.

Q Aside from that study, what was your general knowledge of the area lead you to predict by way of the compaction or loose spreading of the sediments on the bottom of Shallow Bay?

A Well, as I said yesterday when I talked about the consolidation problems, I was speculating. One thing that we do know is that the west side of Shallow Bay is being cut back rather rapidly by waves. It appears to be an older part of the delta plain. It's higher than the eastern side, which is lower and I think, younger. The west side is being cut back rather rapidly and the presence of permafrost -- of frozen ground beneath Shallow Bay suggests, to me, that Shallow Bay may be an area which has relatively recently come into existence so that you have a situation where relict permafrost is present. It is degrading and perhaps, therefore, there would not have been enough time for the sediments to consolidate and they may be

in the process of consolidating, at the present time.

Q Well, I'll be coming back to that later with you sir. Perhaps, if I could return to you Mr. Shearer, you've told us a great deal about your knowledge as to scouring and I understand you to say -- or do I understand you to say that the scouring process enhances the movement of sediment on the bottom?

WITNESS SHEARER: I don't know that I actually said that, but I can see that when scouring happens, you would release some of the sediment that had deposited on the bottom and compacted and perhaps set it back into the water column and it would continue to move with the current.

Q So I suppose in a sense, like plowing the bottom?

A Yes, sure.

Q What would that do, in your view, to bottom sediments that had oil entrapped around them? We've heard something in the past few days about the sinking of oil around sediment particles.

A Right, sort of, you mean the tar ball concept?

Q Yes.

A I imagine it depends upon the density of these things. If they were less dense, they would sort of sit on the bottom as a very thin film and almost be moved back and forth with wave action and the sediments might not move at all. They may be just continually moved, depending upon what wave

action you needed on the surface to give you the necessary velocity to mobilize them on the bottom. If they were quite dense, say as dense as sediment particles, they would just be deposited within the sedimentary column with the other sediments being brought out of the Mackenzie and just fit into the sedimentary column.

Q There is a possibility I take it though that the scouring process, in terms of stirring up oil sediment on the bottom would add to the danger posed by that sediment?

A I think it would add to it, but I don't think it would be as much as say what wave action would do.

Q Let me ask you whether there is any possibility that the scouring process, in relation to that kind of sediment would enhance the biodegradation possibilities for that?

A I can't really comment on that.

Q Mr. Lewis, do you have any comment on that?

WITNESS LEWIS: No, I haven't. I have no knowledge of --

Q Now, you refer, Mr. Shearer, in you evidence to the placing of the silo that the offshore drilling company's proposed to use and you say that the silo is planned to contain the wellhead below the maximum level of scour. I take it you're satisfied that this could be done technologically?

WITNESS SHEARER: I think so.

Q And that the only problem is knowing the maximum depth that you have to use.
A Correct.
Q So, that what you're talking about, as I understand your statistics, is a silo that is about say ten meters, at most. It runs to a depth of ten meters below the ocean floor, since I think you put ten meters as your maximum scour depth below the -- they don't all go that deep.
A I think that maybe when one considers the specific location of where you want to drill, you could do a side scan survey and locate the scour with maximu m relief and it may be three or four meters, and it's probably not ten because that was only found in one area. So that -- say it was three or four meters, you would put the silo in -- set the silo in far enough so that the top of the B.O.P. stack, or the blowout preventer was, say, a meter or so below the scour with maximum relief in the particular area you wanted to position your well.
Q I take it if you wanted to be really conservative, you would take as your maximum depth, the deepest scour that had been found in the southern Beaufort Sea area, rather than simply in the neighborhood of the proposed hole?
A Right.
Q That would be about ten meters.
A Yes.
Q Now, you also spoke about

both yesterday and last time you were here, of the possibility of running flowlines along protected areas, given sufficient knowledge of scour locations. I take it you see that as at least theoretically possible?

A I'm not quite sure I understood your question.

Q You spoke of deep channels which were perhaps old river beds which might be areas protected from scour.

A Right.

Q Could therefore be used for the running of flowlines?

A Right.

Q Yes. That, at the moment, is only a theoretical concept, I take it. There isn't anywhere near enough information to allow that to be considered as an immediately practical solution.

A I think if, today, we were propositioned with say a discovery in a given area and we were to look at possible alternatives of putting in flowlines and where would we put them, we could certainly go first to the channels, the offshore channels that are close to this area, and would look at them in the first instance.

Q And you're satisfied that there's sufficient information about precise locations of those channels to allow them to be used even in the near future?

A Well, they would be the -- this is the first place you would look to and you would do a

detailed survey to obviously delineate it in more detail.

Q Now, one of the other things you spoke about was the possible complications to offshore drilling because of the presence of undersea permafrost. I take it the kind of thing you're referring to there are the casing problems which arise when one drills through permafrost. Is that so?

A Correct. It would be the similar problems you would have drilling on land through permafrost.

Q Yes. That was my question. I take it you're not suggesting that there is any enhanced difficulty offshore in drilling through permafrost as compared to drilling onshore through permafrost?

A Only the problem of the particular surface weather conditions which you don't have to deal with on land.

Q Yes, that's the problem that relates to all offshore drilling, not simply the permafrost aspect of offshore drilling.

A Of course.

Q But as to the particular problems of mastering the permafrost down the drill shaft, those problems are no worse offshore than onshore.

A I don't think so.

THE COMMISSIONER: You don't think -- does that mean you agree or disagree. I --

A I guess I agree.

MR. GOUDGE: I assumed he agreed, sir. Now, let me ask you to turn to page seven of your prepared text. You refer at the bottom of the page or in the last couple of paragraphs to:

"permafrost and associated surface hydrate prolems that are encountered in exploration drilling on land as being problems likely to exist offshore as well".

What do you refer to when you refer to "associated surface hydrate problems"?

A Well, what I mean there, the problems that they've had in some of the holes in the delta when they get just below the permafrost. They encounter frozen gas and these sometimes give kicks that -- I can't really talk on it with any knowledge, I just know they run into problems at that level.

Q At that level, right. But once again, you're not suggesting that those particular problems are any worse offshore than they are onshore?

A I'm not suggesting they're any worse. No. They may be different because of the different permafrost -- the different temperature regime offshore. You saw yesterday that the permafrost model for offshore is somewhat more complicated -- while I didn't go into the onshore one, but it's gone through a number of stages of melting and refreezing and the base -- I don't think the base of the permafrost offshore is in equilibrium with the particular surface temperature of -1.5, -1.8°C. So that, I think

you might be able to say that the problems won't be any different, but I wouldn't guarantee it.

Q I don't fully understand why you say the problems offshore might be different in this particular area of surface hydrate.

A Well, let me just explain it, try and get this out a little better. On the Tuk Peninsula, or the delta, there's a layer of permafrost varying from 300 meters to 500 meters thick and I think, in equilibrium with the surface temperature of roughly -10°C, so that the base of the permafrost is not shifting in reaction to a change in surface temperature. We saw offshore that it was very similar some 15,000 years ago. We might have had the same situation we have on land now. But since sea level rise, the base of the permafrost is now moving upwards in reaction to a much lower mean annual temperature on the surface of this -- on the bottom surface, of -1.5°C.

Q You mean higher mean annual temperature?

A Yes. Right, sorry. Higher. So I don't really know what changes the bottom, let's say the base of the permafrost 15,000 years ago -400 meters than say the present base. I don't know where it is, but I have a model of where it may be at say -200 meters. I don't know what's happened in between that -400 and -200 meters.

Q I see, are you suggesting that there may irregularities in the bottom of the permafrost that may trap the hydrates?

A No, I'm not. I'm just saying that I don't think we really know if there is any -- going to be any differnce or not.

Q What you're saying is there is some difference in the permafrost regime offshore as compared to onshore and you suspect, although you have no knowledge, that it may have led to possible different hydrate problems?

A O.K., I'll agree with that.

Q Now sir, going back to the evidence you showed us yesterday concerning scour, I took it from your slides yesterday that the two principle mechanisms for obtaining knowledge about scour are the echo sounder and the side scanner of fish or whatever you called it. Is that right?

A That's correct. The eco-sounder looking straight down and the side scan sonar which gives you a picture somewhat similar to an air photograph or a radar picture.

Q In interpreting scour and its characteristics, you put together the information gathered from those two sources?

A That's correct we --

Q That's where your information comes from.

A Well, we did try and do some sampling with a submersable in the center of these scours, but it was so cloudy on the bottom, we couldn't.

Q You couldn't see a thing,

eh?

A We couldn't really tell where we were. We could feel them with a submersable. We sort of became negatively buoyant and slid down these things, but -- so we knew they were there physically, but we couldn't really see them.

Q Yes. You've spoken to us about the relief of the scour, and I take you to mean by that the depth of the scour marks. What about the width of them. When you showed us the slides yesterday of the side scanner -- is that what you call it?

A Side scanner. Side scan sonar.

Q Yes. How wide physically are the marks that were indicated on the slides?

A All right. Perhaps I should have pointed that out more specifically. It seems to vary from twenty and thirty feet wide to -- I think we found some up to 300 feet wide.

Q Your analogy of pin on the plywood board did me in, I think. They're really very wide marks, are they not?

A Of course. The plywood board was supposed to represent the polar pack, roughly 3,000 miles across.

Q Now, let me turn you in specific terms to the possibility of ice scour in Shallow Bay. First of all, I take it you yourself have done no research as to the presence of ice scour in

Shallow Bay?

A No, I haven't.

Q What would your general knowledge, though of Shallow Bay as an area and, particularly, the characteristics of ice scouring in the southern Beaufort Sea that you spoke to us about yesterday lead you to predict about ice scour in Shallow Bay?

A Well, I wouldn't expect -- you wouldn't expect winter polar pack getting in that far because it's in the shorefast area and I also wouldn't expect in the summer many pressure ridges or ice islands to get in that far. But I feel, that in the springtime, in spring floods, you may get a lot of pieces of old surface ice of the Mackenzie coming down there and perhaps forming a jam or being, by the current, being pushed along the bottom. A couple of times, flying over there in the fall time, you can see the-- lots of, I guess you call them scour -- lot's of scours on the edges of the channels which had happened during spring flood, well presumed to happen during spring flood at higher water levels.

Q This is rather a different kind of ice scouring, though, than what you were describing in the Beaufort Sea, isn't it? I understood you to describe in the Beaufort Sea ice scour due primarily to the entrapment of ice islands or pressure ridges in the pack ice.

A Of course, very different.

Q That's the worse kind of

scour, I take it. Scour can also be be caused by, presumably wind blown ice islands in open water, but that's not so powerful a force.

A No. Not at all.

Q But the ice scour you're now referring to, as I understand it, would be ice driven by the water pressure of the breaking Mackenzie.

A Correct.

Q Yes. You would anticipate to come back to Shallow Bay, I take it, that there might be some ice scour on the bottom of Shallow Bay, judging from what you know about water pressure and the marks that you have seen caused by ice on the banks of Shallow Bay.

A Correct.

Q Now, Arctic Gas has had prepared a document which Mr. Marshall brought with him at the beginning of the week called,"A Report on a Shallow Seismic Survey in Three Areas of the Mackenzie Delta", and it refers to, in part, Shallow Bay. I take it you've not read this study since it only arrived at the beginning of the week. There is in it, though, -- there is in it an echo sounder profile which, I take it, is one of the two information sources you would use in plotting possible scour marks on the bottom of a water surface. Is that correct?

A That's correct.

Q That document is an attachment to this report and when I finish the questions, sir, I would like to have this marked as an exhibit

along with the report. Now, you'll see as you look at that, Mr. Shearer, that it appears to indicate an echo sounder profile running, really, across Shallow Bay and I think that's the A - B line.

A Correct.

Q Now, that is at the pipeline crossing. As I understand it, and you tell me if I'm explaining it correctly for the record, that line indicates the lower half of the diagram shows the geographical path that the echo sounder took in crossing Shallow Bay. The wiggly line indicated A - B on the upper part of the sheet, shows the pattern it found on the bottom in making that crossing.

A That's correct.

Q Yes. Now if you would look at the A - B line, up above, it appears to me to be very wiggly.

A Yes.

Q That's a layman's interpretation of an echo sounder line. Do those wiggly lines tell you anything or allow you to conclude anything about whether any of the troughs in the lines might have been caused by ice scour?

A Just give me about ten seconds to calculate a horizontal scale on it, and then I'll be able to give you some --

Q Oh yes, I should have -- by all means. I think you'll find that it's about 1,000 feet to the inch.

A A thousand feet to the inch, O.K.

Q Now, I'm advised that it contains a vertical exaggeration of thirty-five. That means absolutely nothing to me, but it may help you.

A As long as you've got the horizontal and the vertical scales together, you can get a -- visualize, roughly, what -- I would say at a thousand feet to the inch, some of these could be possibly, scours; although most of them, the major features seem to be a little wider than most scours. One comment on the scours I have seen on the edges of the channels flying over the Mackenzie are beyond resolution of this equipment, I would think, at this scale. Certainly, we wouldn't -- like a scour a foot wide --

Q Can you explain that to me I don't understand what you mean by "beyond resolution".

A Well, the scour or something goudging into the bottom a foot wide and a foot deep and the length wouldn't matter. Let's assume we just crossed it at some point. This particular line, the width of the pencil line here is a lot more than the -- in terms of width, anyway -- it's a lot more than one foot, so that to show up a scour one foot wide and one foot deep would be just -- I don't think you'd be able to resolve it. I'd have to know what the orginal equipment was to see whether they've drawn this thing by, in fact, just generalizing from a high resolution record. If you had the original record, you might be able to tell a lot more than looking at something like this.

Q I see. Perhaps at coffee, you could have a look at the report. I don't know, frankly, whether that information is in the report, but if you wouldn't mind looking and telling us if you can add to your conclusions about that as a result of looking at the report. There's one other line that -- well, just to capsulize your view of the A - B line, which is the major crossing line, you say that you think some of the markings there may indicate ice scour, but that's as far as you're prepared to go?

A That's correct. I gather the A - B is not all the way across Shallow Bay. It's just the west shoreline. Is that correct?

Q Yes. It runs out from the west shoreline and how far would depend on transposing the scale.

A Right. O.K. It may be about two miles offshore. Yes.

Q Yes. Now, again from a layman's point of view, it appears to me that the bottom is very uneven and you say that some of those unevennesses may be due to scour. Would you have any explanation for the others if they're not due to scour?

A It think it's possible in the springtime to perhaps get some ice jamming in the area and you would have the increased currents around these pieces of grounded or jammed ice and you could have current erosion.

Q Water scour in other words?

A Water scour, sure.

Q Now, just to give us an example for the record, what are some of the maximum depths shown in the marks that may possibly be scour on the A - B line? Can you read that?

A Twenty feet -- Eighteen, twenty feet. This is water depth you're talking about now?

Q No, I'm talking about scour depths from the --

A Oh, O.K., sure. The maximum might be four feet, five feet.

Q Yes. That's what it appears to you from that line?

A Correct.

Q Yes. Now, if you'd look at one other thing that I think strikes you in looking at that document, arises in the D - E line. Can you find it on the document?

A Correct, I have.

Q It runs at a diagonal across the A - B line, looking at the lower half of the sheet.

A The D line actually is almost parallel to the A - B line.

Q Yes.

A It's a thousand or 1500 feet further north, but it's --

Q If you look at the bottom traced by the D - E line, you'll see, in once instance, a very deep hole, apparently.

A Correct, yes, down to about

45 feet, I guess.

Q That is a hole 45 feet below the surrounding bottom?

A No. It's 45 feet below the surface.

Q How far below the surround--ing?

A Twenty-five, thirty below the bottom.

Q Yes. Do you have any possible explanation for that?

A The first inclination, when you look at something like that, is to assume it's part of a -- it's the real channel of Shallow Bay and you would say that this is where the major currents are, but if this is a line that's parallel to A - B, A - B should also have this particular channel in it, which it doesn't. So that it seems to be an isolated hole and have nothing to do with channelization; so that the only thing I can say, is that maybe it's, again, erosion -- water erosion, due to constriction in the springtime of flood waters around grounded ice and jammed ice.

Q You wouldn't think that particular hole would be due to ice scour?

A Not at all.

Q Now, the report itself from which that document is drawn, says on page three in the last paragraph:

"it is anticipated that the change in bottom profile from smooth on the banks to rough in the deeper water is due to ice scouring,

however, this cannot be confirmed from echograms alone, so no definitive statements can be made without further investigation".

In light of what you said, do you have any further comment to make on that statement made by the authors of this report?

A One thing occurred to me when I was looking at this hole. A lot of people talk about thermokarst melting and I don't -- it just -- I would like to know the temperature regime in this area -- the average temperature regime and I think, possibly, it's -- a number of things come up if the west shoreline of Shallow Bay is being eroded at a great rate, one could calculate how far offshore this particular hole is and it could possibly be melting within permafrost which -- at the position where this hole now exists, it was once dry land and above -- not part of the river channel, and I would assume, possessing a certain thickness of permafrost underneath it. As you have channel migration, this particular point becomes part of the channel, moves further out into the channel as the channel moves further westward, or the edge of the west side of the channel moves further westward. If your temperature regime here -- your mean annual temperature regime changes, maybe you have particular melting of permafrost in that area and you may have a hole develop because of melting of permafrost.

Q Localized permafrost?

A No. Localize melting.

MR. BAYLY: It strikes me that a

lot of the questions that Mr. Shearer is being asked are "guess what's in the report", and to my way of thinking, it might be sensible for us to take a short break and let him have a look at the report.

MR.GOUDGE: By all means, sir, that would be helpful.

MR. BAYLY: Then he could comment on what's in it.

THE COMMISSIONER: All right. How much longer do you think you'll be?

MR. GOUDGE: Well, I'm almost finished with Mr. Shearer unless he comes up with anything after looking at the report. I then have a number of questions for Mr. Lewis.

THE COMMISSIONER: Well, we'll take a break now, and then, perhaps when Mr. Goudge is finished we can treat ourselves to another break before your next panel starts. I just didn't want it to be thought that if we broke now, this was the only break we'll have this morning.

(PROCEEDINGS ADJOURNED AT 11:03 A.M.)

(PROCEEDINGS RESUMED PURSUANT TO ADJOURNMENT)

MR: GOUDGE: Well Gentlemen, you've had a chance to look at the report now and let me ask you a few specific questions and then if you have any general comments on the report I'd be grateful if you'd make them.

Q First, Mr. Lewis, you've had a chance now to examine the echo sounder scan,or whatever you call it. I wonder if you have any views as to whether the markings indicated on the AB line in particular might be caused by scour.

WITNESS LEWIS: Yes I do.

Q First, before you answer I take it that you're familiar with the echo sounder process and have interpreted these kinds of scans before.

A Yes, I have.

Q Adnausium Dr.Fyles advises me. Would you please indicate what you think that scan might indicate.

A I think there are several things to consider in the interpretation of this record. One is -- I should say that the record was taken in September of 1975, that's in the fall, when, of course, there has been no ice in the area, moving through the area for a number of months. So that's the first thing to consider. The second thing to consider is that Shallow Bay is the front of the Mackenzie. There's a tremendous amount of sediment being brought into Shallow Bay from the channels of the Mackenzie River and that a considerable portion of this sediment will be deposited in either, permanently or

mostly temporarily in Shallow Bay. So we have a lot of sediment coming in. We have a lot of sediment being dropped in Shallow Bay, perhaps to be moved again at some stage, but still we'll have a changing bottom, one that will be having sediment deposited and then picked up and eroded, and moving through. So, if scour occured in the spring time; in May, June, I think it highly unlikely that evidence of that scour would persist through to September of that same year. I think the bottom would be too mobile for that.

Q Sorry. What then would the reasons be for the kinds of markings that you see on the A-B line.

A You see similiar markings in echograms taken across some of the wider Mackenzie Delta channels. I think they're bars; current features related to the movement of sediment, to the deposition of sediment.

Q Yes, I cut you off before. Did you want to add a thought to--

A I just would like to make it clear, however that the fact that I don't think that these particular marks are scour marks, does not mean that I don't think that scour would occur in the area. I think it could well occur in the area, but to find out whether or not it does you'd have to do your echo sounding immediately after the passage of the ice in the spring.

Q I take it, like Mr. Shearer you would be very dubious about ice scour due to floating ice islands in Shallow Bay because of the lack of depth

in the water. I-- well more than dubious, I'd say that it would be impossible. For one thing, although the depth here is approximately say 10 feet on average across Shallow Bay, further offshore it's shallower than it is here. It's less than 6 feet and you're not going to move a very large piece of ice in through 6 feet of water, or even 10 feet.

Q What would your view be of the possibility though, of ice scour occurring at break-up in Shallow Bay ?

A I've flown over Shallow Bay at times when there were large ice jams in Shallow Bay. I think there is certainly a very definite possibilty that scour does occur. I couldn't make any quess whatsoev on the magnitude or the frequency of that scour.

Q By magnitude, I take it you mean depth.

A How deep, how wide, certainly. Well the only quess I would make is that it would be a lot less severe than the offshore scouring which occurs under the pressure of the polar pack.

Q I take it, Mr. Shearer, you would agree with that as well; that any ice scour that may occur through break-up and water pressure would carry with it less destructive force than polar pack ice scour.

WITNESS SHEARER: Correct, much less.

Q Now Mr. Lewis would you turn to D-E, the D-E line on that diagram, the one with

the very deep hole, and could I ask you for your views as to what might cause that ?

WITNESS LEWIS: Yes, you could.

Q Would you answer, please?

A As Mr. Shearer said, since the feature does not appear on the A-B line, it is possibly probably not a channel, and therefore is a hole of some sort. As to what might have caused that hole, there are a number of possibilities, one of which is the melting out of ground ice in the sediments beneath Shallow Bay. I don't think that is a very likely possibility.

Q Why not ?

A This kind of thing can occur along the Tuk Peninsula or the Yukon coast, where there are large thick layers of massive ground ice in the sediments, but to my knowledge there have been no large thick layers of massive ground ice found in the sediments of the modern Mackenzie Delta. So I think that's an unlikely explanation .

A perhaps more possible one is that in the channels of the Mackenzie Delta , this is on the delta plain itself, we find holes which look very much like this hole in their echo sounding traces. They tend to form in the channels. They tend to form near bends in the channel and they're associated with turning of the flow, possibly with ice jamming-- with flow around ice jamming, and I think some mechanism of that sort would be a more likely origin for the hole.

Q How fast does a hole like that fill in, given the sediment load in Shallow Bay ?

A I have no idea. I do know that sediment is moving rapidly through the channels of the Mackenzie Delta, and yet you find scour holes of greater magnitude, greater size depth than this which persists throughout years. They last throughout the season and they last from year to year and they tend to stay in the same place. So it's possible on the delta plain, for a hole of that size to exist and to continue to exist, in spite of the movement of sediment, because of the current pattern.

Q Yes, when you say the delta plain, do you take in Shallow Bay, or--

A I don't. On, when I talk about the delta plain I'm talking about channel flow and I think in a relatively narrow channel , certainly narrow in comparison to Shallow Bay.

Q Is that sufficient flow in Shallow Bay to produce that kind of hole ?

A I'm surprised at seeing it.

Q So, while it's a more likely explanation, it's still not all that likely.

A It's very much conjecture, yes. I don't know of any direct data available on currents in Shallow Bay; certainly currents which might cause something like this.

Q Sticking with the delta plain, does that kind of hole, caused by current appear suddenly, or does it take years to build up ?

A I have no idea. My experience with scour holes on the-- and we're not talking about ice scour here-- my experience with scour holes con-

sists of having discovered by echo sounding, existing scour holes and continued echo sounding over those scour holes to see that they maintain themselves throughout the open water season and that, coming back the next year and the year after and finding the same scour hole in the same place, but I've never observed the,sort of initiation of such a hole.

Q So, you have nothing to tell us about the creation of these holes.

A No.

Q There's no doubt though that if one of these holes were created along the route of a buried line it would expose the line at that point.

A Yes.

Q Do you know of any research that is going on to discover the origin of this kind of hole ?

A I have heard at various times in the past few years of a number of people who are going to look at these holes, but I have not seen any results. So, to my knowledge, there is no investigation going on at the present time.

Q Now let me finally ask you, whether, in light, I take it in light of your comments you would disagree with the passage I read from the report to Mr. Shearer, indicating that the author thought the markings on the D-E line might possibly be due to scour .

A Yes, I would disagree with that.

Q Now, Mr. Shearer, after

reading the report and looking at the echo sounder scan closely,do you have any further comments on the information revealed there, in so far as ice scour or water scour is concerned ?

WITNESS SHEARER: No, I don't, just a clarification of your last question to Mr. Lewis. You meant ice scour when you said scour, is this correct ?

Q Yes.

A O.K. I would agree that that particular hole is not an ice scour feature.

Q And the markings on the D-E line,-- of the A-B line, sorry, of which there are a number would be unlikely to have been caused by ice scour.

A I agree.

Q I take it though, you would both agree that if echo sounding were done right after breakup one might anticipate a line showing the results of ice scour.

A Correct.

Q Mr. Lewis?

WITNESS LEWIS: Correct.

Q Now Mr. Lewis, let me move to your evidence if I might please. You spoke to us yesterday on page three of what you called segmented circulation patterns, and I think you said you'd divided the coast up into a number of segments, and sediment sinks exist, as you put it, within the segments. Is that correct ?

A Yes, it is.

Q And they collect sediment

and would therefore collect oil.

A Oil would tend to move toward the sediment sink of each segment.

Q Ah -- And you said, as I understood you, that these sinks also spawn life because of the existence of the sediment.

A Yes.

Q Now, you as well said that lagoons exist, as I understood you, where there may not be the similiar high life content as there is in these sediment sinks.

A I don't believe I mentioned their life content. I would see no reason why the lagoons would have any lower biologic component-- why some lagoons would have a lower biologic component than other areas and other sinks.

Q Sorry . You referred to certain areas, perhaps newly breached lakes that you said might serve as appropriate places to put oil once it had been spilled.

A The context of that remark is first of all that it's made from the point of view of preventing a spread of a spill. However, within the breached lake or lagoon, or whatever it was, there would be a tremendous amount of damage done, so I certainly wouldn't say at all that these areas are any lower in biological productivity; that great damage would occur, but the idea would be to limit the extent of that damage.

Q And I assume that if the biologists told us that there were lägoons or breached

lakes that were of low life content, they would be by far the best places to localize any spill that occurred.

A I assume they would. From my talks with the biologists, they haven't mentioned anything like this.

Q Yes. I wonder if assuming those lagoons could be postulated to exist, whether your theory of sediment sinks could be used to combine with such lagoons, so that spilled oil on its way to the sink, so to speak, might be diverted into lagoons of low biological content. Is that a feasible theoretical way of controlling oil spills?

A It's a theoretical way that one might do it. I think the problem with the whole situation there is that in lagoon areas, in sediment sink areas there's very little water depth and it would be very hard to operate in those areas. So, although it would be a nice idea, the feasibility of it is another question.

Q You're very dubious about the feasibility because of the lack of water depth?

A Yes.

Q

At page four of paragraph 23 of your evidence you told us a good deal about spits, bars, and beaches, and low lying delta areas as being both biologically important and exposed to inundation from storm surges. There are I take it, behind the spits and bars, low lying coastal areas, which as well may be at risk from such spills.

A Except in front of delta areas, or in the immediate vicinity of delta areas, usually

behind spits, bars, and lagoons, there are cliffs of varying heights, so that the area which is subject to inundation by sea water behind the spits, bars and lagoons would, in most cases, not be great.

Q There are though, many areas along the coast which are comparable to the low lying delta areas,in terms of their exposure to storm surges. I'm thinking for example of a number of the areas along the Tuk Peninsula itself.

A The lake basins for example.

Q Yes.

A Yes.

Q And there's no doubt that storm surges pose a real risk to those areas, as well as the low lying delta areas.

A They do pose a real risk to those areas.In a partially drained lake you're talking about a water surface . You don't have the same extent of above normal tide low lying land, for example, that you would have on a delta.

Q I see. So the threat to low lying land is mainly concentrated in the delta, rather than the coastal areas.

A I would think the major threat is to the delta areas. The various spits, bars, and lagoons are a second major area.

Q You spoke,as well in connection with storm surges of the driftwood line that you notionally drew across the delta, or the outer delta,as I think you referred to it. Just so we'll have it's locat-

ion, much like the Barry route, where does that line fall in relation to the Shallow Bay crossing. There's no doubt it's in shore of the Shallow Bay crossing.

A On the west side of Shallow Bay, which is an older, higher part of the delta, the driftwood line appears to be quite close to the edge of Shallow Bay. On the east side, however, the driftwood line is considerably south of the proposed pipeline crossing.

Q Yes, and continues to run south of the cross delta route as I recall.

A It runs south of the cross delta route from the east side of Shallow Bay, all the way over to Richards Island.

Q Right. Until you pick up the main north-south line, which the driftwood line crosses at some point.

A Yes.

Q Now, what about the production plants or the scrubbing plants at Nig, whatever it is and Taglu.

THE COMMISSIONER: Niglintgak.

MR: GOUDGE: Thank you sir.

Q Are they north of the driftwood line as well ?

WITNESS LEWIS: I'm not completely familiar with the locations-- proposed locations for those plants, or on what type of land form they're on. I know they are north of the driftwood line.

Q I see. That's the question I was asking you. You know that, there's no doubt the

driftwood line comes to the south.

A Assuming that they're on the modern delta.

Q Well, you know where they're proposed to be located.

A Generally.

Q Yes, and you know that their proposed location is to the north of the driftwood line you spoke of.

A Yes.

Q Now, finally in connection with storm surges, and simply to assist my understanding, Mr. Milne mentioned yesterday that there can be winter storm surges. You didn't refer to this in your evidence and I'm wondering whether you're familiar with winter storm surges.

A Yes, I am.

Q He spoke of one in particular that took place I think in January, 1974.

A Yes.

Q I take it these are surges which occur before the land fast ice freezes entirely.

A I don't know.

Q I'm curious as to how a storm surge can occur which affects water levels if there's a complete ice cover.

A We're getting beyond my field of expertise. I'm familiar with the particular storm which occurred in January of 1974.

Q Well, let me ask you about that. Did that occur after the landfast ice had moved out to the pack ice ?

A I don't know. I do know that the landfast ice from Shingle Point, excuse me, from King Point which is west of Shingle Point as far as the Alaska border and as far as I went offshore which was 20 or 30 miles, was broken up into pieces by that storm. I also know that from talking with Bob Mackenzie at Herschel Island, who happened to have been at Kay Point during that storm , that Kay Point spit was completely flooded, that the Babbage Delta was completely flooded by water during that storm.

THE COMMISSIONER: What was the date of that storm ?

A It was in early January 1974.

MR. GOUDGE:

Q I think it was January 6th, sir 1974, and my only concern was to know how you could have a storm surge once the landfast ice had solidified and met up with the pack ice, and I take it, Mr. Lewis, you're simply not able to assist us on that.

A I really can't comment on that.

Q Now on page five of your prepared evidence--

THE COMMISSIONER: You're saying, where do you get the water from ?

MR: GOUDGE: Yes sir. I just don't understand that. I take it just to complete it Mr. Lewis, the only winter storm surges that you know about

are surges that took place when there was, either as a result of the storm, or before the storm, open water to be blown around by the storm ?

WITNESS LEWIS: I'm not sure whether the open water, in the case of the January storm I talked about was cause or effect; whether it was there before the surge occurred or whether the surge occurred and caused it.

Q On page five of your prepared evidence,you spoke to us about a possible circulation as a result of the storm surge, inward from Shallow Bay, right across the delta with drainage out the East Channel. I take it that is in some sense a worst case and how likely is it to happen?

A Well, as I said,we really have no idea of what the circulation pattern over flooded areas of the delta would be during a storm surge. I mentioned a possibility of salt water being drawn in on the Shallow Bay side, and fresh water being diverted out East Channel, solely on the basis of a model study done by Dr. Henry, taking a typical storm surge, and plotting the changes in water level at the shoreline caused by that model storm surge. In his model he discovered that because of the offshore geometry that, during that surge you could expect a three meter rise at the head of Shallow Bay, and at the same time only a one and a half meter rise at the mouth of East Channel, and this suggested to me the possibility of water moving from the higher area in Shallow Bay toward East Channel. But this is very very speculatory because modeling a surge is one thing, but here we don't

just have a surge, we have a river and the river was not included in the model, and to ignore the river on the Mackenzie Delta is obviously a major fault in the model.

Q Yes. Were that to occur though, and were it to occur at the time of construction in Shallow Bay, obviously there would be a consequence that for the East Channel, by way of transportation of materials from Shallow Bay.

A If oil was included in the water, which is the context I was talking about it in, it might be possible then for oil to be drawn in and dropped on the modern delta, in spite of the river discharge coming out the other way. On the delta, a surge can cause flooding of large areas, as I've talked about with respect to the areas south of the driftwood line. But of that area we don't know what percentage of it would be covered by river water and what percentage of it would be covered by salt water.

Q Nonetheless this represents a specific example, theoretical though it may be, of a reversal of flow; that is, into Shallow Bay as opposed to out of Shallow Bay.

A Yes, it does.

Q This is a specific example of a general phenomenon that can occur in the delta as a result of storm surges, or even spring floods, is it not? The reversal of flow ?

A In a sense. A storm surge which causes a rise in sea level can back up the river water and cause the levels of water in the river to rise, regard-

less of what is happening at the upstream end. The current is still in a downstream direction in the main delta channel. What it can do however,is to cause flow from those delta channels into the many delta lakes, which are connected by minor sub channels.

Q Yes, and that is a reversal of the normal flow caused by the surge.

A Well, those channels are reversing flow channels, in that when the water level in the major distributary channels is rising, water will flow from the channel into the lake. When the water level on the major distributary channel is falling, water will flow from the lake into the distributary.

Q Yes, and I take it there are perhaps two general sets of circumstances where that may happen. A storm surge may cause a reversal of flow into the delta lakes, or spring breakup may cause a reversal of flow into the delta lakes.

A Yes, or additionally summer rainstorm floods in the river basin.

Q Yes, and this reversal of flow tendency is something that is obviously a factor to be seriously considered in terms of the carriage of any polluting material in the delta.

A Yes, it is.

Q In other words, polluting material spilled in the delta may be carried downstream in ordinary circumstances or may be carried back up into the delta lakes when you get this reversal of flow.

A Yes it could.

Q Now sir, pages six and seven of your prepared evidence, you spoke to us of the difficulties of stabilizing permafrost coasts, and in particular you've spoken to us, both yesterday and earlier about the coast near Tuk, as being a coast that provides great difficulty because of erosion.

A It provides great difficulty because of erosion, due to the presence of massive ground ice.

Q Yes. I wonder whether you've given any thought to any ways that might be used to stabilize that erosion, and let's take the Tuk coast around Tuk as an example.

A I've given thought to it. I've been involved in consultations with the people at the Department of Public Works, who are directly concerned with the problem of attempting to stabilize the shoreline around Tuk. It's a very difficult problem.

I could say that in the long term, the sea is going to win.

Q What can be done in the meantime to prolong the agony?

A Well, one thing is to ensure that there is a supply of material to the beaches in front of the cliffs which protect the cliffs. The second thing is some structure; some engineering structure of some sort to decrease wave attack during a storm on the cliff.

Q A break-water, I suppose.

A That would be one possibility.

Q So, you need stabilizing

material, on the one hand, and engineering devices as well.

A Yes.

Q Yes, and by stabilizing material would you be thinking of riprap for example?

A Yes, that would be a possibility.

Q Now the Tuk coast is but one example, I take it , of the general problem you recited of eroding coastal areas, which you said posed a threat to the bringing ashore of pipelines.

A Yes.

Q Yes, and I take it, you see that threat arising from the rapidly changing coastline due to erosion.

A Yes, and particularly to the presence of massive ground ice, both in cliffs and beneath the sea bottom, in the shallow water areas.

Q You're not suggesting though are you that the entire coast is of that character.

A No I'm not.

Q In fact there are many places along the coast where it would be possible to run a flowline ashore without running into the kind of problem you're speaking of.

A Yes.

Q For example, in bays which may have a shallow gradient, for example, there may not be the kind of erosion problem you speak of.

A I would think that anywhere that massive ice is not a major factor, would be a much

safer area to bring a flowline in shore.

Q And those areas do exist in considerably large numbers along the coastal area that you spoke of, in general terms.

A Yes they do.

Q Now as to spits and bars, you spoke about them to us in some detail, and there's no doubt, as I understand you that they both grow and shrink through deposits on the one hand-- well let me ask you, do they both grow ? You showed us slides of the growth of spits, for example . Are there any circumstances under which their size would diminish ?

A Their size would diminish if for any reason, the supply of material to them was changed, decreased.

Q What kind of speed are we talking about on the growth side, with these spits ?

A I believe I mentioned a figure for Nunaluk Spit of over 2000 feet in 18-20 years.

Q And do you have any examples of the opposite process, where a spit or a bar has decreased in size due to the interruption of the supply to it.

A No, we don't.

Q I see. So you can't tell us anything obviously about the speed at which that might happen.

A No.

Q Now, earlier, when you gave evidence before this Inquiry, in December, and again yesterday, you spoke in some detail of the dredging or the

possibility of dredging a permanent harbour at Tuktoyaktuk. I take it, from your evidence that you feel that is possible without permanently affecting the erosion of the cliffs, provided the spoil is put in the right place.

A To the best of my knowledge, it would be a possibility if the supply of sediment to the beaches in front of Tuktoyaktuk is not interrupted, and if , by placing any spoil from dredging on the down-stream side of the channel, if that spoil will be redist-ributed and continue on its way in front of the cliffs, then I would say it would be a less serious situation.

Q I think you said last time when you were here, that to produce this harbour you would have to dredge some distance offshore.

A Yes, I did.

Q Yes, and you put it in terms of miles but you didn't specify how many miles.

A No, it was a topic that had been brought up ,on the spur of the moment, so to speak, and I hadn't prepared.

Q Without asking you to do something that you're not willing to do, would you be prepared to put a mileage figure on the dredging required to produce a permanent harbour at Tuk ? How many miles offshore would you have to dredge ?

A I still wouldn't be prepared because I still have not seen any of the plans for the dredging, and I still do not know to what depth they plan to dredge.

Q I take it though, that your

concern would be satisfied if the material taken from the bottom,in dredging , were placed on the downstream side of the opening to the harbour.

A I'm a bit hesitant about saying yes. My concern would be considerably decreased. I'll go that far.

Q Without doing that,you would say the effect, the added erosive effect on the cliffs would be very substantial.

A I think it would be, yes.

Q Yes. Assuming that the initial dredging spoil were placed downstream, and that the opening were kept dredged and that the continued dredging spoil was put downstream, is that sufficient to keep the cliffs from eroding faster than naturally ?

A The reason I'm hesitating is because I'm not clear in my own mind about the processes, the rates at which sediment would be picked up again after it had been deposited as spoil and moved along the cliffs. So, while I think that that would certainly decrease any damage that might occur along the cliffs at Tuk, I'm not willing to make that an absolute.

Q Until more study is done of what might happen to spoil deposited downstream, and where it might go.

A Yes,and until more study is done as to what is happening now, under natural conditions;how much is moving, when it moves--

Q How much sediment is continuing to be deposited at the cliff base, so to speak.

A Yes.

MR. BAYLY: Perhaps Mr. Goudge could repeat that. We had the answer and question going at the same time.

MR. GOUDGE: Did you get that? Well, the answer's all I'm interested in.

MR. BAYLY: The answer was just 'yes' what was the question?

MR. GOUDGE: I think , Mr. Lewis, you and I are in agreement that-- about something.

THE COMMISSIONER: Why don't you tell us, Mr. Lewis, where you stand on this.

WITNESS LEWIS: On the sort of general situation of dredging, you're talking ? My stand is that there is undoubtedly a considerable quantity of material moving from the north, south toward Tuktoyaktuk. It provides a significant part of the material on the beach, in front of the cliffs, at Tuk settlement, and this material is--, this beach material protects the cliffs from even more rapid rates of erosion than are presently ocurring .

Now, if we dredge a channel in the near shore zone, to open up the harbour at Tuk; now this would be north of the settlement, we would interrupt the along shore movement of material ; if this material is placed-- this dredged material is placed on the downstream, the downdrift side of the dredged channel, I think it is possible that the damage will-- that possible damage to the cliffs at Tuk, through a decrease in supply, will be minimal, but I'm not prepared without much more evidence

on what is going on at the present time, and what might go on if this action is taken. Until that is known, I'm not prepared to say definitely that it would cause no damage.

MR. GOUDGE:

Q Now sir, this dredging of the harbour, I take it, would in your view, would be a specific example of, well what you would want to know before you would feel sanguine about it going ahead, would be similiar to what you would want to know before you would be sanguine about the removal of gravel from spits, for example.

A Most definitely so.

Q Yes. Now let me come to the theory that you put to us yesterday about delta sediment compaction. As I understand you, you say that you feel there may be a possibility of compaction occuring in the sediments of Shallow Bay.

A Yes.

Q And that is because this is an old part of the delta ?

A That is because it's a part of the delta, which may have recently thawed and therefore may be subject to natural consolidation of the thawed material.

Q I take it, you mean may be thawing; that is permafrost under Shallow Bay may be in the process of thawing.

A Yes.

Q And as a result, creating

newly thawed sediments, which may, over time, compact.

A Yes.

Q I take it, before any prediction could be made about the kind of compaction that might be anticipated, you would have to know first the rate that the permafrost was thawing, and secondly the nature of the sediments to determine what kind of compaction would occur when they thawed.

A Yes.

Q And that task, I take it, is one that would, in your view, require a good deal of research.

A It would require significantly more than is known at the present time. I don't make any claims to be an expert in the consolidation theory. I brought the point up only because, as one reads the literature on world deltas, one of the major topics is on consolidation of the sediments, and yet when one looks at the literature, the work being done on the Mackenzie Delta, the topic is not mentioned. So I thought it was perhaps time that it should be mentioned and should be considered.

Q And possibly studied ?

A Yes definitely.

Q Would you extend this theory of compaction beyond simply Shallow Bay, to low lying parts of the delta ? Let me perhaps elaborate that. There's no doubt that there's permafrost over large areas of the low lying delta, that should something happen to the surface cover, melting of the permafrost might occur, and that the sediments thereby melted, might be subject to compact-

ion according to the theory you gave us yesterday.

A I think this is a definite possibility and I think it's illustrated by the fact that lakes are forming on the outer delta plain at the present time through ponding of water,due to some cause or other, subsequent degradation of the permafrost and perhaps the consolidation after that point. So any process-- any action which for example removed surface vegetation which might change the thermal regime,and hence the thickness of the active layer , which might lead to ponding; could lead to the development of a lake, and that the process would tend to accelerate because, once you have a pond and you have a thawed area underneath the pond that can then expand so--

Q You need a triggering event and once you get that, your theory comes into operation.

A I think that's a definite possibility.

Q Now, let me move to permafrost distribution in the delta, and let me ask you this general question. Could you provide us with your view as to the general distribution of permafrost in the outer delta ? Is it a continuous thing or spotty, or what ?

A I'm making my statements purely on the basis of what I have read in the literature and on direct experience in other older, more southerly parts of the delta.

Permafrost has been measured to depths of 60-100 feet in the outer delta. In all areas of the delta; wherever there is a lake which does not freeze to the bottom in winter , or a channel which does not freeze

to the bottom in winter, there will be anunfrozen zone underneath those water bodies which may extend right through the permafrost. So we have a perforated situation. We have general permafrost and wherever there is lake or a channel we have a hole perhaps through the permafrost.

The other characteristic of permafrost in the outer delta is that it is a grading; it is not an equilibrium. This is found out from direct measurments, so it is a grading at the bottom. It is extending itself deeper. It is also a grading at the top as new sediment is deposited on the outer delta, the active layer thickness would tend to stay much the same and the frost table would move up, so it's a grading in both directions.

Q How does that square with the relative thicknesses that may be found throughout the delta, and I'm speaking here of what we were told by the producers, where for example, at Taglu we've been told there are about 1600 feet of permafrost, whereas at Nig there are 500 feet and perhaps at some points along the cross-delta route, such as under the lakes or channels, that you spoke of, no permafrost.

A Well the gas plants are at the edge of the modern delta and it looks to me that they are near the Pleistocene delta, which is a much older part of the delta, which has a much thicker permafrost beneath it, and from looking at this report that you gave me during the coffee break that there is gravel beneath modern delta sediments. Now in the Shallow Bay area, further west and in the Ellice Island area, it is all modern delta and

it's all new sediments, so perhaps I think in the Taglu area you're dealing with an older material which has a thin veneer of modern sediments on top of it.

Q Let me ask you about one other piece of this rather complex picture, and that is do you have any knowledge about the presence of thawed zones within the permafrost? Does that occur in the delta, as far as you know ?

A Yes.

Q And by, within the permafrost I mean, within it, looking at it from the side, rather than from the top.

A Yes. The holes, of course beneath lakes and channels would be called tallicks. Also it seems that in some parts of the delta, at least, wherever you have a permanent winter snow drift, thick snow drift, there is a significant degredation in the permafrost table. At the place where I worked near Reindeer station there's a permanent-- a thick snowdrift which occurs every year along the side of a channel, and the depth to permafrost beneath that snowdrift is about 35 feet, so that's an unfrozen layer caused by another process on the delta.

Q In general terms then, there's no doubt that the permafrost regime in the delta is one that has many complexities.

A Yes.

Q Finally sir, let me turn to what you can assist us with on your knowledge on Mackenzie Delta sediments. To begin with I take it, you've done a

good deal of work in this area.

A Yes, I have.

Q And in particular, your doctoral work is related to this area.

A Yes, it is.

Q What can you tell us about the different kinds of materials that comprise the near surface part of the delta ? What kinds of materials are we speaking of ?

A In terms of texture of the mineral sediments we're speaking of anything up to a fine sand, perhaps medium sand at the coarsest, with large quantities of silt and also large quantities of clay so very fine sediments; essentially no gravel in the modern sediments except that which may have been ice rafted down from further up the river. We also are speaking of a fairly large proportion of organic material. As I mentioned yesterday it's not a large proportion in comparison with other deltas of the world, but it would certainly be a large proportion in comparison to most of the spits and bars, for example along the coast.

So, two major components then; the mineral component, being very fine, and the organic component.

Q And can you make any comment for us on the differing engineering properties of those two materials, in their various states, frozen and unfrozen.

A Perhaps, could you be a bit more specific?

Q Well, let's take the mineral component , if you will, of the delta, first. What comments would you make on the engineering properties of that substance as a support for construction or for a pipeline ?

A I think that you can't really look at it without considering the fact that it's frozen and its engineering properties are related to a great extent, the fact that it is frozen, and that any activity that thawed it, would cause problems that might not occur in a more southerly location.

Q And in a thawed state, I take it, because it is fine sediment, it may be subject to very substantial erosion or compaction .

A It would be subject to compaction. It is a cohesive sediment because it is so fine. It has the ability to form vertical walls. A sand for example, a pure sand would not. It would tend to be deposited at its angle of repose which would be considerably less than a vertical cliff. So, I'll stop there for the moment.

Q Now, I take it, there are, amongst these sediments, lake deposits, levee deposits, and for example, point bar deposits.

A Yes.

Q And do those sort of sub-compartments display any differences between them if thawed after being frozen.

A Well, channel bottom deposits and point bar deposits; that is deposits associated with active river processes tend to be coarser. They're the

sands which you find on the delta, and would have the engineering properties of sands. No massive ice, no significant access ice.

Lake sediments, on the other hand are much finer, have a higher organic content usually, running 20-30 percent clay and would have all the problems associated with construction on clays. Levee sediments are somewhere in between. They represent material which is deposited by the river as it floods its banks.Most of the material tends to be deposited right at the edge of the channel banks and to build up to form a levee, and this is generally in what we would call a silt, finer than the channels but coarser than the lakes.

Q Yes, and these three categories that you've spoken about are all found in the delta.

A Throughout the delta.

Q Yes.

A Both on the present surface and at depth where you might run into an abandoned channel which has been buried, you could find the whole spectrum at depth.

Q Yes, and I take it, the complexities presented by these three categories might be worthy of study in advance of construction or engineering.

A Very definitely. People tend to classify the modern delta as a unit in comparison to various parts of the areas surrounding it, but--

Q What's your comment on that?

A It's a very,very complex

unit and very variable within itself and I think we tend to forget that.

Q Yes. Breaking down the unit, would you like to break it down beyond the three sub-categories that I referred you to earlier or is that a satisfactory break-down for the purposes of engineering planning?

A I think that the-- we have deposits associated with river channels, delta channels. We have deposits associated with delta lakes and we have the gradational deposits between the two and I think that would certainly be--

Q Those are the three main sub-categories.

A Yes, in terms of the sediments.

Q Yes.

A Within those sediments we have the various manifestations of frozen ground, including ice wedges, which-- and the development of ice wedge type typography which creates its own, perhaps different group.

Q Its own problems ?

A M-hm.

Q So that the ice content is an aspect of the problem, I take it, as well, varying organic contents within the three sub-categories might produce differing engineering effects.

A Yes.

Q So the picture's complex.

A Very.

Q Now, lastly, Mr. Lewis, you

say on page five that the Mackenzie is one of the largest deltas in the world, and I take it, that you say it's 8000 square miles approximately.

A That is the area of the sub-aerial delta plain; that is the delta plain above normal tide.

THE COMMISSIONER: What do you mean,modern delta ?

A We talked about the modern delta as the currently active delta, and Richards Island and the Tuk Peninsula is often called the Pleistocene delta.

THE COMMISSIONER: Yes, the old delta.

A It's an abandoned Mackenzie Delta, an old one.

THE COMMISSIONER: Now, the 8000 square miles, is the modern delta or the modern delta plus the old delta ?

A Just the modern delta.

THE COMMISSIONER: Right.

MR. GOUDGE:

Q What would the modern delta plus the old delta constitute ? Do you have any idea ?

A I really don't know, and I should add,of course that the Mackenzie Delta doesn't stop at the shoreline; that there is a further very large area in the near shore which is generally classified by most people who study deltas, as being part of the delta plain. I believe represents another 3-4000 square kilometers. I'd

convert that but I did the measurement in kilometers so I can remember it.

Q Let me ask you,where, in terms of world order, the Mackenzie Delta would rank in terms of size.

A It would be in the top ten.

Q How close to the top ?

A I don't know.

THE COMMISSIONER: Well, you're ranking it with the Nile, the Amazon, the Mississippi and the Niger and so forth. Is that it?

A Yes,and even more importantly , with the Lena , and some of the big deltas in the Soviet Union.

THE COMMISSIONER: Yes . This is the only delta in the Arctic coast of North America of anything like the same size as the Lena and these others. Is that right?

A Yes, that is correct.

MR. GOUDGE:
Q Out of the top ten, Mr. Lewis how many others would be in Arctic surroundings?

A Two or three, I can't remember which, of the Soviet deltas.

Q Do they, in any way, approximate the size of the Mackenzie ?

A They're larger than the Mackenzie.

Q Are they similiar in character or do you know that ?

A I'm just very,very generally

familiar with them and they are similiar--

MR. MARSHALL: These questions are geographic, Mr. Goudge. There was an interesting article last two months on Siberia and the river Ob's delta.

MR. GOUDGE: Maybe, Mr. Marshall, you can give evidence this afternoon.

MR. HOLLINGWORTH: Is this the hit-parade of deltas ?

THE COMMISSIONER: Is it on your list of documents ?

MR. GOUDGE: It's better than most.

WITNESS LEWIS: I must admit I haven't seen the article that Mr. Marshall refers to, but yes to my knowledge they are similiar, and the Yukon Delta is somewhat similiar. The much smaller Colville Delta on the Alaskan North Slope is very similiar.

MR. GOUDGE:

Q Although much smaller.

A Although much smaller.

MR. GOUDGE: Thank you. Those are all the questions I have, Mr. Lewis.

THE COMMISSIONER: Well I assume it must be around 12:30 or--

MR. EVANS: Mr. Commissioner if we are going to be finished examining these witnesses, I have one more question, of one these witnesses, that I would address to Mr. Lewis.

THE COMMISSIONER: Go ahead.

CROSS-EXAMINATION BY MR. EVANS

Q Mr. Lewis, in respect to artifical islands for drilling in shallow water areas, now I understand that these are in many cases constructed on top of deep deposits of sediments. Now constructing it out of gravel or aggregate, could this result in islands built for production purposes becoming unstable over their life, say 20 years ?

WITNESS LEWIS: Do you mean that by putting the weight of an artificial island on the sediments of the outer delta ?

Q Yes.

A Would this consolidation process I've been talking about, perhaps lead to some instability?

Q Yes, that's right Mr. Lewis.

A My answer would be,I don't know, but I think it's a possibility and again, someone had better find out before and not after.

Q You didn't wish to comment further on that possibility ?

A No, it's a possibility in the sense that you are adding weight to sediment. In the offshore areas in which they're working it's possible that there will have been no permafrost developed as of the present time. So , in that situation you're not concerned with a suddenly thawed permafrost. It's the situation-- you're concerned with what would normally happen when you place a load on sediment of that type.

Q So, your position is that

you feel that before this is done that sufficient research should be carried out to determine what the effects would be ?

A Yes, and I'm sure it would because I don't think that in that particular situation where permafrost is absent, if it is absent, that it's a different problem from that which has been run into by engineers in many locations in the world, from that point of view. It's a different problem in the sense that it's in the Beaufort Sea, as we talked about yesterday, from other points of view.

MR. EVANS: O.K. thank you.

THE COMMISSIONER: I take it there's another panel ready to give evidence this afternoon. I leave it to Counsel to decide whether they want to hear their evidence in chief, and then adjourn, or whether they would prefer to cross-examine the panel this afternoon. I don't know how long their evidence in chief is likely to take, but if it's anything like Dr. Milne's, I think that's about all we could handle, this afternoon.

MR. GOUDGE: Sir, if we could take their evidence in chief, it will take, I would think, a couple of hours to read,then would probably elucidate a better cross-examination if it were left until Monday.

MR. BAYLY: They're going to be here over the weekend, so that we can start with them again on Monday. It's not as compact as Mr. Milne's evidence, I assure you and won't take as long.

THE COMMISSIONER: I'm not complaining about Dr. Milne's evidence. It was very,very important, but we had to be at the top of our form just

to absorb it as it went along.

MR. EVANS: Mr. Commissioner, I'd be in favour of doing the evidence in chief, this afternoon and then cross-examining first thing Monday morning.

THE COMMISSIONER: Right, well I think that you're in the majority.

MR. BAYLY: Mr. Commissioner, I have the curriculum vital of witnesses on this panel here and I'm going to photocopy it at lunch. It was just given to me last night, and if Counsel want to see it before I photocopy it and then get a copy of it after lunch, I'd be happy to show it to them when we adjourn.

THE COMMISSIONER: Well, I should say that on my desk this morning there arrived from a friend of mine who's in the department of Indian Affairs a book containing the collected letters of Groucho Marx, and if it's thought it should be entered as an exhibit I would be happy to arrange that.

MR. BAYLY: I don't think that would be relevant, Mr. Commissioner.

(LAUGHTER)

THE COMMISSIONER: We'll adjourn till two, then.

(PROCEEDINGS ADJOURNED AT 12:25 P.M.)

(PROCEEDINGS RESUMED AT 2:05 P.M.)

THE COMMISSIONER: Well, we'll come to order.

MR. BAYLY: Mr. Commissioner, if we can begin.

MR. GOUDGE: Just before Mr. Bayly begins, sir, I meant to file at the end of the last panel as an exhibit, the report that I asked Messrs. Lewis and Shearer to comment on, perhaps I could do that now. I understand we can mark the exhibit, and Mr. Marshall can provide us with another copy for filing purposes.

MR. BAYLY: You have a new panel before you this afternoon, and if I can introduce them, they are from your left, Dr. Norm Snow, and Mr. R.K. Pettigrew, and Mr. William J. Logan. You have prepared evidence before you as well of Messrs. Pettigrew and Snow, and Mr. Logan is a member of the panel without prepared evidence, but who is available for cross-examination, and who may be able to assist in filling any gaps that there may be.

These witnesses have all been sworn.

R.K. PETTIGREW,
NORMAN SNOW,
WILLIAM J. LOGAN, sworn:

DIRECT EXAMINATION BY MR. BAYLY

Q I wonder if we could start from left to right, if you gentlemen could review your biographies as they relate to your experience, that is connected with the evidence that you're giving today.

Dr. Snow, could you begin?

WITNESS SNOW: My position is acting head of Environmental Assessment Section of Water, Lands, Forest and Environment Northern Natural Resources and Environment Branch, Department of Indian and Northern Affairs. I have a Bachelors of Science in zoology from the University of South Hampton, and a PHd in oceanography, also from South Hampton University.

My professional experience is university lecturing in zoology at the University of Manitoba, research into invertebrate physiology and ecology of benthosand zooplankton, also at the University of Manitoba.

I was engaged in environmental impact research with the Department of the Environment, for the Federal Government, in the Northwest Territories, and also the Yukon; and environmental impact assessment with the Federal Government, Department of Indian and Northern Affairs, to date.

MR. BAYLY: Mr. Pettigrew?

WITNESS PETTIGREW: I attended the University of Saskatchewan, and took a Bachelor's Degree in geology; left the university in 1939. From 1945 until about 1970, which is about 25 years, I was employed with Shell Oil Company in various parts of the world, as an exploitation engineer, and production engineer, associated with the development activities of oil gas fields in Trinidad, British West Indies, Venezuela, parts of the U.S.A. and Canada.

In 1971 I spent a year abroad

in Australia, North Africa, in geological engineering consulting. In 1972 I joined the Environment Canada in Ottawa, and spent a year with Policy Planning and Research Director. The last three years I've been in Edmonton with the Environmental Protection Service of Environment Canada, and my work has been involved with the development of an environmental emergency organization. Some of the prime objectives have been to develop an integrated response mechanism to spill emergencies, reporting procedures, contingency planning, research and development aspects.

Q Thank you. Mr. Logan, would you review your qualifications as well for the Inquiry, please?

WITNESS LOGAN: My educational experience, primary education experience, was a Bachelor of Applied Science degree in Mining Engineering from the University of Toronto.

Following that, I spent from 1959 to 1971 in the base metal mining industry primarily with Falconbridge Nickel Mines. The work was on mine - mill development and operations and the areas of work were Arctic and central Quebec, northern Manitoba, and Ontario.

In 1971 to 1973, I did graduate studies in fisheries biology at the University of Guelph and than joined the Environmental Protection Service on Environment Canada in Burlington Ontario.

I am presently the head of the Center of Spill Technology and our prime responsiblity is development and assessment of countermeasures equipment and techniques to combat accidental discharges of oil and hazardous chemicals.

MR. BAYLY: Mr. Commissioner, copies of the biographies of these three panel members have been filed with the Inquiry. If we could start with you Mr.

Pettigrew, I understand in the first instance you have some reports that were not listed with your evidence, that you may be referring to today, and if you could give the Inquiry the names of those and their authors for the record?

WITNESS PETTIGREW: The first report I've used in some of the preparation of the submission, the title is "Oilspills and Spills of Hazardous Substances". This is a publication covering oil and special materials control division, division office of the Water Programs, program operations, U.S. Environmental Protection Agency, Washington. D.C., 20460.

The second report is "Departmental Contingency Plan, Environmental Emergency", dated June 15, 1973, and this was developed by the Environmental Emergency Branch, in E.P.S., in Ottawa.

The third report is an agreement between the Department of the Environment and the Ministry of Transport, with respect to responding to the problems of oilspills and other hazardous materials. The date is March 25, 1975. This was developed in Ottawa, between the two departments mentioned.

The next report is a report of the Environment Canada Task Force, on the Mackenzie Valley Pipeline application, north of 60 degrees. This was developed under the chairmanship of Dr. Zoltai, Canadian Forestry Service, Edmonton, Alberta.

The next report is a "Review Of Petroleum Spill Containment Dykes In The North", developed by Environmental Emergency Branch, Edmonton,

September, 1974.

The last one is "Guidelines On The Use And Acceptibility Of Oil Spill Dispersants", developed by the Environmental Emergency Branch, Ottawa, August 1973.

MR. BAYLY: Now, I understand, Mr. Pettigrew, that before beginning with your prepared text, you have a view graph that you'd like to refer to and if we could could have the lights turned off perhaps --

A Just before we take a look at one view graph, I have a few comments that I would like to -- I'd like to lay just a little bit of ground work before we look at that, if that's all right.

Q Please go ahead.

A As the submission will cover various aspects of environmental emergencies, spill emergencies, I believe that it will be of some value to define a few of the terms that we're going to be using, in a way to state briefly what we're trying to do, and where I think we are in a state of preparedness; a little bit about our objectives, and possibly areas of concern. By doing this, as I said, with the aid of a very few view graphs, possibly one or two slides a little later on, I would hope that the content of the submission covering contingency planning of the Mackenzie Valley Pipeline, will be put into a little clearer perspective and maybe made just a little easier to understand.

First of all, I think a definition of what we think of as an "emergency", I should spell this out. An environmental emergency is the sudden,

unexpected or apprehended introduction into the environment of a pollutant in sufficient quantity to pose a direct threat to man or other forms of life.

In E.P.S. and Environmental Emergency Organization within E.P.S., a word on authority. The authority for Environment Canada's response to an environmental emergency, is derived from Federal legislation, and primarily the Fisheries Act, the Government Organization Act of 1970, and in addition the Cabinet has directed Environment Canada to undertake coordinating and related functions for Federal responses to environmental emergencies. Our general policy is to encourage development of a coordinated state of preparedness, throughout Canada, by all governments and industries, as well as to reduce the possibility of environmental emergencies, through improved prevention.

A brief statement or two about objectives. We -- one, to recommend and implement effective preventative measures; two, delineate responsibilities of all agencies by national contingency plan for environmental emergencies from which integrated operational plans can develop both regionally and locally; three, to assess the threat of the ecological sensitivity, and the national state of preparedness, to conduct research and development, and evaluation of environmental emergency technology, to coordinate a provision of on-scene technical advice on environmental matters, and to conduct on-scene operations when no other agency has assumed responsibility for adequately protecting the environment.

In terms of a plan of action, a few comments under that rather broad heading. We feel it's important to encourage provinces, municipalities, and the private sector to develop a capacity to respond to environmental emergencies, and the Environment Canada role should be one that shifts gradually towards one of monitoring, and a provision of technical advice also and including such things as data collection, evaluation prevention, public information, research and development of environmental emergency technology; we feel is an important aspect of upgrading preparedness, to obtain better equipment, and better techniques, and to provide the type of knowledge that's required for training purposes.

Still in this broad range of action plan, we must rely on the expertise of other elements of Environment Canada for advice and guidance on environmental matters. THis includes fisheries, wildlife, et cetera. Those experts have been pre-designated and made aware of the needs, and are available on rather short notice.

I might point out here that we have in E.P.S., in Ottawa, an Operations Center, charged with collecting information on spills from across Canada, spill events, emergency events. THeirs is a communications and information role, for E.P.S. as a whole. They have threat analysis capability, and retrievable backup operational capability, and are linked to a computer system in the States, from which we can draw a good deal of technical information, if and when

required.

Organization structure is required, in the form of a national contingency plan for environmental emergencies. In order to spell out and clarify who is responsible for what, and for what functions are to be performed in times of spill emergencies, and E.P.S. does have a responsibility to ensure that contingency plans are comprehensive, and effective to the degree that they ensure rapid response.

I would like to talk just for a minute about what I refer to as a preparedness chart. In my terms, this is a concept and this is something that I'd like to just develop with you. It won't take very long, maybe five minutes; but if we look at this, I think this will be -- will lay a base line of understanding for many of the things that are contained in the submission that we'll be getting into.

Now on the vertical scale we've got threat versus preparedness level. What we're really comparing here -- there's four things really, and in order to deal effectively with environmental emergencies,we think it's essential to examine the matter as one that involves a set of the parameters which you see defined there. There's the threat, there's preparedness. Preparedness, another word for preparedness is response capacity, there's the risk, and all this is related to a time scale, across the bottom. I'd like to point out that the threat level, that horizontal line in red, fluctuates up and down to some degree. It may not be a straight line but it's -- the threat level is really affected by the increase in human

activity, the more drilling rigs that you have in the delta and the Beaufort Sea, the more likelihood that there's going to be something go wrong with one of them sooner or later.

The more trucks you have on a highway hauling fuel, the more likelihood there's going to be an accident and spill, that sort of thing.

Now, the threat level can be affected or reduced by improved prevention, the small green arrow on the right. THe green line, the green curved line, is the one of preparedness that I think is the focus on this curve. Thinking about preparedness, there are three basic elements to preparedness, and these come from contingency planning.

THere's the plan itself, contingency plan, which is really the organization. There's the trained personnel, to execute the plan. There's equipment and material, and there is operational improvements. Under that last category, you can't see it from back there, operational improvements, include research and developments, new equipment, new techniques, and new knowledge. Also under operational improvements there is training, transfer of knowledge, and training of personnel to use new equipment and to become familiar with new techniques.

The risk is the area between the two curves, the one with threat level and preparedness. and as we -- what is rather obvious in this concept really, or approach, is that we reduce the risk by getting prepared, and if we can bring these two lines together, this is the objective.

Pettigrew, Snow, Logan
In Chief

Just before leaving this I would point out that we're not very far, in my opinion we're not very far along the line of preparedness. I suppose it's only been four or five years that people have really conscientiously begun to think about and plan for and learn how to handle emergencies and particularly spill emergencies under adverse conditions, under a great variety that we know, and so this has been a rather short learning phase. You can pretty well -- you can put a time frame on that bottom line, suit yourselves. In my terms I look upon that as, if we visualize it, maybe as a ten-year scale, 10 or 15-year scale, split into about three parts, I feel we're over on the left-hand side some place, in the lower section of that preparedness curve. We have a long way to go.

We have much to learn in this business of how to handle spills and emergencies under a great variety of conditions.

I'll start with the introduction of the submission.

MR. BAYLY: Yes, please, Mr. Pettigrew.

A One brief statement before starting to read this. The contingency planning involves, in my terms it involves things like prevention, preparedness, coordination , communications, training, research and development identification, threat identification, sensitivity indentification.

Introduction. During the construction and operation of gas and oil pipelines through the northern Yukon and Mackenzie Valley, there

will be large volumes of petrochemicals transported, stored and utilized along the route. Arctic Gas has estimated in their application that about 400,000 tons of fuel and methanol would be used in the construction of their gas line.

Fuel will be transported to the site by road, the Mackenzie River barge system, air transport and ocean shipping. Their application goes on to state:

> "Where fuel must be stored, a separate area will be set aside for storage tanks, and dikes will be placed around the tanks. These areas will be constructed in such a manner as to provide an impermeable barrier.
> When small volumes of fuel must be stored, liquid fuel storage tanks of the bladder type (up to 1,500 barrel capacity) will be used. For larger fuel storage requirem ents, steel tanks (up to 5,000 barrels capacity) may be used instead of or in combination with bladder tanks."

The U.S. Environmental Protection Agency has estimated that there have been about 13,000 spills of oil substances in the United States annually since 1970. Spills have occurred during the building of the Alyeska Pipeline itself. It seems inevitable, therefore, that despite the best intentions and preventive measures taken by a proponent, spills will occur along the Mackenzie line. Concern for how such spills could affect the living environment and social

well-being of local residents is, therefore, an important issue.

The present gas line applicants and future oil line proponents make frequent reference to oil and chemical spill contingency plans which will be written to handle any spills during the construction and operation of their lines. The gas line applicants outline in some detail the spill preventative measures planned for the facilities during their construction and operation. The applicants clearly recognize the seriousness and scale of the problem.

The following paper, prepared for the Environmental Emergency Branch of Environment Canada, contains recommendations on information which should be incorporated into a comprehensive contingency plan and site specific action plans for spills of oil and other hazardous materials attributable to pipeline projects along the Mackenzie Valley routes.

Definition and objectives of a contingency plan. A contingency plan is a complete organizational package which provides a pattern of co-ordinated and integrated response to a spill of oil or other hazardous materials in order to protect the environment from damaging effects. The objectives of such a plan are:

(1) To assure that health and the environment are provided with adequate protection by developing appropriate preparedness measures to minimize the damage caused by those spills which preventative measures have not been able to avoid.

(2) To outline effective systems for detecting, discovering and reporting the existence of a pollution spill.

(3) To provide for the prompt execution of measures to restrict the further spread of the pollutant.

(4) To outline the techniques for cleanup and disposal of collected pollutants.

(5) To provide the protection on actions to pay cleanup costs and damage claims, and to prevent recurrences of similar incidents.

The potential for spill emergencies. Spills of petroleum or other hazardous products could occur from a large number of sources and operations in a pipeline project. These include ocean and river shipping, marine vessel to shore transfer operations, on-shore storage facilities and tank truck transportation. Concentrated methanol solutions could be spilled if there was a pipeline rupture during pipe testing. In addition, other materials such as high temperature lubricants, X-ray photographic chemicals, spent engine oils and fluids, sewage and drinking water treatment chemicals and rust inhibitors could also be released into the environment.

If containment and cleanup of spilled materials was not prompt, toxic effects could result in the damaging of aquatic life, waterfowl and fur-bearing animals downstream of the occurrence. Downstream intakes for industrial or drinking water supplies could also be affected. In winter, spills could migrate undetected under snow and ice cover to areas a long distance removed from their source. Ice and

low temperature conditions would make cleanup operations of spilled material difficult, slow and extremely costly.

Small spills would likely only affect the local land area or water body near the source of the material. Because the proposed gas and oil pipelines parallel the Mackenzie Valley for much of their route north of 60, any major spills could enter this water system through tributaries and pollute large areas downstream. This would seem a particular threat during the operation phase of an oil line.

A summary of some areas sensitive to petrochemical spills. The most sensitive area for potential oil spill damage is the Mackenzie Delta. The aquatic habitats found in the delta lakes, streams and Mackenzie River main channels provide extensive areas for a diverse and large fish population. The Mackenzie River estuary provides overwintering areas for several species of anadromous fish and Arctic cisco, least cisco, inconnu and other species used in the main channels for spawning. Broad and humpback whitefish, inconnu and two species of cisco use the channels for overwintering and migration routes to spawning areas. Smaller streams, connecting lakes and larger channels are often spawning areas for grayling, pike, humpback whitefish, and least cisco. Lakes of sufficient depth and size provide habitat for several species. Yaya Lake and Parsons Lake are two important habitats for lake trout and grayling respectively.

The delta is an extremely

important area for domestic and commercial fisheries. The main channels and the delta coast are the locations of extensive fishing activities. Important fishing camps are centred around Aklavik in the Western Delta; Kugmallit Bay and the East Channel are the areas of most eastern fishing activity. Whitefish Station and Kittigazuit are the main fishing camps in Shallow Bay. An important commercial fishery is centred around the East Channel-Holmes Creek area, and most of the catch is sold in Inuvik. A large oil spill in the delta or near the mouths of the Peel or Arctic Red River could cause serious damage to domestic and commercial fisheries in the area.

The Mackenzie estuary is also an important area for calving whales. Shallow Bay and Kugmallit Bay are nursery and calving areas for beluga whales during the summer months, and provide good hunting for local residents. An oil spill could disturb the calving females and their young.

The Beaufort Sea coast estuaries and lagoons are important overwintering, feeding, and possible spawning areas for char, grayling, cisco, whitefish, inconnu and other species. Domestic fishing is carried out at Shingle Point, Komakuk Beach and Herschel.

Important fish resources and fisheries are also present on the Yukon North Slope and interior routes. The Old Crow and Porcupine drainages have many spawning, overwintering and domestic fishery areas on them downstream of the present pipeline crossings.

Oil spills along the Beaufort

Sea coast and in the Mackenzie Delta could result in serious damage to large concentrations of waterfowl which use these areas during the summer months. Whistling swans, snow geese and other types of waterfowl and shore birds account for almost three-quarters of the 52 species of birds using the delta.

The Mackenzie Delta is one of the major waterfowl breeding areas in North America. The most important waterfowl nesting or feeding areas are located in the western outer delta, with the largest concentrations being found along the coast of Mackenzie Bay from Mallik Bay to Shingle Point. The East Channel is of moderate to high importance to waterfowl, and the north-eastern coast of Richards Island is of moderate importance to swans.

The Beaufort Sea coastal plain is another important area for resting and feeding activities. Waterfowl species concentrate around river delta areas, nesting near lakes of the coastal plain. The Mackenzie River Valley is used as a flyway by migrating birds during the spring and fall. During these migrations, stops may be made along the Mackenzie River for feeding or resting, but these stops are short-term only. Oil spills on the Mackenzie during these migrations could prove harmful should the birds come in contact with the spill.

The delta is also valuable habitat for muskrats, beaver, otter, mink and other fur-bearing species. Muskrats are by far the most

economically important and support an extensive trapping industry. Muskrats are plentiful from the base of the Tuk Peninsula to the Thunder River. An oil spill in the delta could have serious impacts upon the muskrat population and disrupt the local trapping industry. The importance of the Mackenzie delta to fish, waterfowl and mammals cannot be over-emphasized. Oil spills in the delta could seriously hurt the productivity of the fish and the wildlife resources and directly affect the local residents who depend on these resources for their food and livelihood.

Components of a Mackenzie Valley Pipeline Spill Contingency Plan. Contractors and operators are expected by government to have an appropriate emergency organization to deal with an y spills of oil or chemicals which might occur during the construction or operation of a pipeline through the Mackenzie Valley. Such an organization must have a workable written contingency plan which spells out how a spill emergency would be handled in the vicinity of the pipeline right-of-way, and in areas downstream which could be affected.

The contingency plan for a Mackenzie Valley Pipeline should be concise and uncluttered with extraneous detail. The plan should include the following:

(1) Purpose: This should explainthe operator's prevention and contingency goals, and how it is intended that they be met.

(2) Scope: The plan should include spill emergency

schemes on everything within the right-of-way and the support facilities. It should also take into account accidents or environmental extremes which could originate outside or spread beyond the right-of-way boundaries, such as oil or chemical spills from other operations in the area, flooding, landslides, vandalism.

(3) Corporate policy and responsibilities: A brief point form outline of the senior management decisions on policy matters, legal requirements and moral responsibilities should be covered in this section. The contingency plan should go into some detail on these points. Some policy questions which must be decided upon are the following:

(a) Is containment and cleanup of spills to be done in-house with proponent staff, or using outside contractors?

(b) What staff position levels have the predesignated authority to call out spill emergency containment and cleanup resources?

(c) What staff position levels have the authority to commit the proponent financially to cleanup contractors, and to what amount? One point of clarification there, authority to commit resources needs to be identified and those in positions need to be pre-designated.

(d) What are the relationships to be with other petroleum industry and developm ent operators regarding spill prevention and mitigation in the area? Here again these arrangements need to be thought out in advance, pre-arranged agreements.

(e) What will be the distribution of the contingency

plan and the site-specific action plans in support of it both within and outside the proponent organization?

(f) How are media and public relations enquiries to be handled during spills along the pipeline?

Legislative requirements for the proponent to satisfy, other than those which will be outlined in the permit documentation to construct the line include the following:

A. Federal Acts.

(a) Department of Indian Affairs and Northern Development administered Acts and regulations such as the Northern Inland Waters Act, the Arctic Waters Pollution Prevention Act, the Arctic Waters Pollution Prevention Regulations, Territorial Lands Act, the Oil & Gas Production & Conservation Act.

One point, certain provincial Acts will apply to pipeline matters and to waters south of 60 degrees.

(b) The Department of the Environment administered Acts and Regulations. These include the Fisheries Act, Migratory Birds Convention Act, Canada Water Act, Clean Air Act, Environmental Contaminants Act, the Ocean Dumping Act.

(c) The Ministry of Transport administered Acts and Regulations. These are or include the Arctic Shipping Pollution Prevention Regulations, the Canada Shipping Act, Oil Pollution Prevention Regulations.

B. Territorial Ordinances:

These include the Environmental Protection Ordinance, Gas Handling Ordinance, Public Health

Ordinance. Pertinent parts of this legislation should be summarized in the contingency plan and detailed in an appendix.

The next, component parts of a contingency plan. We have now named three. This one is No. 4, planning and response elements. This part of the plan should explain how the contingency plan is organized and how it fits into other plans in the area and how the emergency response is co-ordinated.

I would add to that that this underlines the need for an integrated contingency plan. Now, under that heading of planning and response elements, there are four recommendations for a Mackenzie Valley Pipeline.

(1) That on-scene commanders be pre-designated for spill accidents within the scope of the plan.

(2) Alternate on-scene commanders be pre-designated to act in the absence of the regular on-scene commander.

(3) Spill response team members and their alternates be pre-designated and each member be assigned to be responsible for the management of one of the following functions: Logistics covering transportation, communications, accommodation; equipment, which might cover cleanup machinery or equipment and materials; manpower, which would cover employees, proponent employees, contracted workers, volunteers; another item is public and press information; environmental matters; legal advice and office services. Any necessary technical, environmental or managerial advisors should be under the direction of the O.S.C. but could work closely with any one

of the spill response team members.

THE COMMISSIONER: Excuse me.

A Yes.

Q The on-scene commander, I don't quite follow this, is he -- does he head the spill response team? And the other members of the team have their designated responsibilities in each of these areas.

A That's right.

Q All right. Sorry, if it's obvious but I wanted to make sure I understood.

A The fourth recommendation under this heading is that spill response centres be pre-designated as the operations co-ordinating centre to implement the action plans for spill emergencies along the line.

An example, there could be Inuvik as a spill response centre for a significant or major spill in the Beaufort Sea.

The fifth component of a contingency plan for the Mackenzie Valley Pipeline is under the heading of response operations. Actions taken to respond to a spill incident can be divided into five overlapping phases.

(1) Is discovery and notification.
(2) Is containment and counter-measures.
(3) Is cleanup and disposal.
(4) Is restoration and payment of damages.
(5) Is Cleanup c osts and fines.

Now under the first one, spill

discovery and notification. These two steps are very important to the action plan. If spills or leaks are not quickly discovered and a good notification system for reporting, the first few critical hours of a spill incident would be lost to the containment process. Incidentally, we believe that the first hour or two are extremely critical in reducing cost and involvement in a spill cleanup. This could result in unnecessary environmental damage, and in this case cost of countermeasure response would rise sharply. Spill discovery could be the result of casual observation or by routine facility checks by the proponent staff and contractors. Notification includes internal proponent organization reporting and external government agency alerting. That affects public and media.

Now under this heading of discovery and notification there are a few recommendations specific to the Mackenzie Valley Pipeline. It is recommended first that personnel manning telephone, and this has to do with the proponent or industry or company, the personnel manning telephone and radio telephone numbers normally available for service to the public, be informed of who to notify in the pipeline corporation if a leak or spill is spotted by a member of the public and reported to these members.

Second, that a spill emergency phone number be circulated to government agencies concerned with spills of hazardous substances from a Mackenzie line into the environment. For instance, Ministry of Transport, Department of the Environment, Department of

Indian and Northern Affairs, to enable them to contact the proponent through suitable channels if they receive reports of or observe spills from the pipeline.

Third recommendation, a documented system of regularly scheduled inspections of pipeline facilities be carried out by the proponent staff to check for actual and potential fuel leaks or spills at key areas along the pipeline and around associated facility property. Systems of automatic alarms for warning of tank farm leaks or oil transfer operation spills should be considered.

Fourth recommendation, a spill notification and information system be instituted in the proponent organization to inform appropriate senior staff and concerned government agencies and potentially affected or involved Mackenzie Valley or Yukon North Slope industries and municipalities of a spill and to keep them informed on containment and cleanup activities. The severity of the spill will generally determine the notification pattern and the extent.

Fifth recommendation, notification be done through a specific pre-designated proponent dispatcher, or his alternate, so that the personnel directly concerned with a spill problem along the pipeline can proceed with the job of controlling the spill.

Under the heading of spill containment and counter-measures, this is the second phase under "response". This phase includes the deployment as directed by the on-scene commander and with assistance and advice from the spill response team,

it includes the deployment of booms, absorbants, vacuum pumps, equipment necessary to contain or neutralize the spilled substance or protect property, for instance water intakes, small craft harbours, bird sanctuaries and so on, protect things like that from pollution. It would also include any measures necessary to stop more pollutants from spilling.

Once again, there are a few recommendations specifically for the Mackenzie Valley Pipeline.

First recommendation under the heading of "containment and counter-measures", that the proponent be a member of the National Emergency Equipment Locator System, which is termed NEELS for short, this is a computerized inventory bank of cleanup equipment available in Canada.

Second recommendation, that trained personnel be available at key installations along the route to handle containment and cleanup equipment. Periodic mock exercises should be held to keep cleanup personnel up-to-date and the equipment in working order.

Third recommendation, containment and cleanup equipment be stockpiled at appropriate intervals along the pipeline right-of-way and at high spill risk installations.

Fourth, that every effort be made to contain any spill on land before it gets to any water body. Because of the steep terrain and the proximity of freshwater systems or the sea in many areas, this could be difficult. Consideration should be given

to fabricating and installing spill barriers in surface runoff ditches and depressions likely to catch oil or chemicals around some facilities.

Fifth recommendation, that a spill be removed quickly from drainage ditches or a tank farm containment dyke area by using pumping systems with skimming heads, commercial or natural absorbants, physical removal and disposal under permit of contaminated ground or burning under permit. If bunker oil is spilled, pumping or absorbing may be impractical because of its high viscosity. In this case, a continuous absorbant belt, conveyor system, special absorbant application or even rake and shovel operation could be necessary.

Still under this heading of "containment and counter-measures", I break it down into two sub-headings:

(1) In the event that containment action fails on land and a stream or river channel operation is necessary, and to continue with the recommendations, under that sub-heading, that booms be deployed at critical points along appropriate shoreline such as across the entrance to important waterfowl and fish resource areas and key water intakes, small boat wharves, bird staging sites, fisheries areas.

Next recommendation, that booms be deployed in river channels at pre-determined sites or prepared access points to contain the spill where the current is not too strong, or to deflect the oil into pre-designated collecting areas along the shoreline if the river flow velocity is high.

Next recommendation, that booms be deployed anywhere in larger bodies where oil can be trapped or corralled. Skimmers may be used to collect oil which has been diverted toward them by means of booms.

Now under the sub-heading,

(2) In the event that containment action fails on land and in a river channel, a Beaufort Sea operation becomes necessary, this is still under the heading of "containment and counter-measures", and further recommendations.

No. 9, that booms be deployed along the Mackenzie River in the delta or in the Beaufort Sea to protect key wildlife, fisheries and harbour areas.

No. 10, booms, skimmers and absorbants be deployed, weather permitting, in areas where floating oil can be contained or absorbed for pickup.

No. 11, that any special methods for cleaning up oil from ice infested waters and oil under ice which might result from experiments being carried out in the Beaufort Sea program, be incorporated into the Mackenzie Valley Pipeline action plan when these are developed by the company concerned.

No. 12, that dispersing materials be used in Mackenzie Valley-Beaufort Sea pollution containment or cleanup operations, only within the restrictive guidelines published by Environment Canada for the controlled use of these materials.

No. 13, that the proponent formalize co-operative spill working arrangements with the other petroleum and industrial operators along the

pipeline route. Equipment purchases by these organizations could then be further co-ordinated and cleanup staffs augmented for maximum efficiency.

Under the broad heading of "response operations" we come to the third phase of counter-measures entitled:

"Cleanup and disposal".

This work involves the actions necessary to remove the pollutant from the water and related on-shore areas using absorbants, skimmers, earth-moving machinery, etc., to physically pick up oiled beach materials. It should also include the collection of oiled birds and establishment of bird rehabilitation centres. Controlled disposal of pollutants and contaminated materials in approved locations where they will not re-contaminate the environment is an important activity in this phase. In an area having the fluctuating river and marine water level environments along the pipeline routes, this work must be done around the clock to prevent high water levels or heavy precipitation moving oil from polluted beaches and ditches to areas which were not previously contaminated. In winter, the oil should be picked up quickly to prevent migration under the snow and ic e. If it gets under ice, efforts should be made to locate and recover oil before spring breakup.

Once again, for a Mackenzie Valley Pipeline, a few recommendations:

1. Drainage ditches and shoreline cleanup be done as quickly as possible with highest priörity on areas

environmentally sensitive. The proponent is expected to have maps showing areas highly sensitive to spills in areas which could be affected by oil and chemical contamination.

2. For cobble and gravel beaches, natural materials or commercial absorbants be spread over the area to absorb the oil, and then be recovered by hand-raking.

3. Liquid oil-water mixtures, spent absorbants, contaminated driftwood and beach materials, be stored temporarily in 45-gallon drums or plastic lined pits, dug above the high water mark.

4. Permanent disposal methods be worked out using oil reclaiming facilities of the proponent or at pre-selected government-approved permanent land disposal sites.

Phase 4. Restoration. This phase covers soil or shoreline material restoration, cleaning of private property such as piers and boats, and restoring to the satisfaction of the appropriate government agency as much as necessary of the living environment such as attempting oiled birds rehabilitation or restocking aquatic resources.

Under "Restoration" again, a few recommendations in regard to a Mackenzie Valley Pipeline.

1. Soil restoration be done with advice from recognized contaminated soil restoration experts who could set up a program specific to the contamination problem at the site.

2. Cleaning of docks, boats and other private property be done on a high priority basis, or alternatively, on

the spot cash settlements be made to enable the affected parties to have their property cleaned by a private company.

3. Recreational beach restoration be done according to agreements reached with local Territorial and municipal officials.

4. Bird and aquatic fauna rehabilitation be done according to agreements with Environment Canada officials. Canadian Wildlife Service could provide advice on bird rehabilitation operations.

Phase 5,which is payment of damages, cleanup costs and finds. This phase generally takes place last but the information and the actions required in it must be recorded in detail from the start of the spill incident. A few recommendations under this last phase, that's Phase 5 of payment of damages, etc.:

1. In order that their work not be interrupted, operational personnel involved in the spill cleanup take part as little as possible in any legal investigations during the incident.

2. All proponent supervisory personnel involved in the incident keep thorough detailed notes of their activities and decisions during the incident.

3. Proponent legal staff be assigned to work with government agencies, cleanup contractors and small claims from boat owners and fishermen during and after the incident.

4. Small straightforward claims from fishermen, private citizens and small businesses be settled quic kly.

Paragraph 6, under the heading of "Overall Co-Ordinating Instructions."

This section should contain all the information required by operational personnel to really understand how an incident would be managed. Recommendations for a Mackenzie Valley Pipeline under that last heading of "Overall Co-Ordination Instructions":

1. Electronic portable communications along -- among the operational personnel be of excellent standard. Next to effective action planning, good communications for alerting personnel and for hour by hour coordination among cleanup forces is the most important operation parameter.

2. Spill cleanup progress briefings take place daily at an operation centre during the period that action is required on an emergency basis. All cleanup staff supervisors, spill response team members, advisors, and so on should be present.

3. That detailed minutes of these meetings be kept.

4. Agreed to courses of action for the spill response team members and their work parties should be summarized in point form and circulated the following morning, in order that no misunderstandings develop.

5. Senior management , press and government agency liaison personnel should attend the daily briefings.

6. Press conferences be held once per day with the on-scene commander and any necessary technical advisers in attendance. The public relations member of the spill response team be available to the press at any time and arrange for tours, telephone facilities.

7. Appendices, non-operational sections of the action plan should contain information on word definitions, who has copies of the plan, the plan up-dating procedures, communications, legal authorities, financial procedures, and a list of non-proponent plans for the pipeline route areas.

For a Mackenzie Valley Pipeline it is recommended:

1. That the contingency plan be distributed to all appropriate proponent headquarters and field staff, and government agencies operationally concerned or having jurisdiction along the route.

2. The plan be up-dated and operationally tested by field exercises at least once per year on a scheduled and documented basis. Plans of these exercises should be submitted to the relevant government agency for review one month in advance.

3. Portable radio and telephone communications be reviewed and use procedures outlined.

4. Legislation applicable to a spill incident along the route be summarized.

5. The non-proponent action plans along the route be listed.

F. of the submission entitled:

"The Roles of Government Agencies".

The Department of Indian & Northern Affairs, through the Territorial Government, assumes operational leadership and management of spills on behalf of the Federal Government in the Northwest Territories for all land environmental emergencies

occurring north of the 60th Parallel. The Northwest Territories Government has formed an Emergency Control Committee to carry out this co-ordination. Serving on this committee are the following Federal Government Departments:

National Defence
Ministry of Transport
Indian & Northern Affairs
Department of Environment
Royal Canadian Mounted Police
The Department of Manpower
Department of Public Works
Canadian National Telecommunications
Northern Canada Power Commission
Northern Transportation Company Limited.

In the Yukon there are differences, and there the Department of Indian & Northern Affairs assumes operational leadership and management of spills on behalf of the Federal Government for all spills which occur as a result of land use operations under a Territorial Land Act permit, and operations that have a water use licence or water use authorization under the Northern Inland Waters Act. Environment Canada assumes operational leadership and management of spills resulting from operations not under such a licence or permit. An ad hoc Committee carries out this co-ordination of spill response. Membership on this committee includes:

Environment Canada
Environmental Protection Service, acting as chairman

Department of Indian & Northern Affairs

Yukon Territorial Government

Both the Game Branch and Highways and Public Works.

For spills originating from offshore mineral exploration or mineral extraction sources such as oil, Department of Indian & Northern Affairs through M.O.T. will lead the response for affected areas in the Beaufort Sea. When the spill originates from a ship at sea or on a navigable waterway, the Ministry of Transport will assume the lead role. Environment Canada will provide guidance to the departments mentioned above, and assist in meeting a federal response. This might include communications networks, expert advice on fish, wildlife, weather and vegetation, technological information on spill counter-measures, properties of hazardous substances and equipment sources in other parts of Canada.

To me that paragraph underlines the advisory capacity that we believe we have. To continue,

When the operator responsible for the discharge of oil or other hazardous materials fails to act promptly, does not take appropriate actions to contain, cleanup and dispose of pollutants, or/if the discharger is unknown, direct Territorial-Federal response actions shall be instituted. This same procedure will be effected in cases where the operator is unable to cope with the situation.

The national contingency plans written by the Ministry of Transport and the Department of the Environment for environmental emergencies describes

the federal organizagional arrangements for emergency responses. A description of the more important Territorial and Federal agencies which should fit into an operator's plan are the following:

1. The Territorial Emergency Control Committee , Yellowknife. This is a senior management body designed to assume the lead role on behalf of the Department of Indian & Northern Affairs in organizing and implementing a response to a major war or peacetime emergency including oil and chemical spills in the Northwest Territories.

2. The Yukon Disaster Committee, Whitehorse, is a senior management body designed to assume the lead role in organizing and implementing a response to a major war or peacetime emergency including oil and chemical spills in the Yukon Territory.

3. The on-scene coordinator, coordinates and directs government pollution control efforts at the scene of a pollution incident.

4. Pollution prevention officers have been located at specific centres to action reports of spills into Arctic waters, on the mainland or islands of the Canadian Arctic which may enter Arctic waters.

5. The local offices of the Environmental Protection Service, Environment Canada, located at Yellowknife and at Whitehorse are to provide technical advice and guidance to federal and territorial bodies on emergency matters.

6. The Federal Inter-departmental Regional Environmental Emergency Team, known as the REET is established on a regional basis. The Pacific team, located at

Vancouver, and the Northwest team, located at Edmonton, would serve as a resource element to the appropriate committee in case of a major incident.

7. The national environmental emergency team is an inter-departmental consultative mechanism at the federal headquarters level.

Any funds spent by the Federal Government for spill mitigation would be recovered from the polluter after an incident.

Conclusions:

1. Construction and operation of gas or oil pipeline -- of a gas or of an oil pipeline through the Mackenzie Valley would considerably increase the risk of petro-chemical spills in the area.

2. There are many aquatic and wildlife resources in the Beaufort Sea and Mackenzie Valley which could be seriously harmed by spills of oil or chemicals.

3. The impact of spills in the area could reduce the value of these living resources for subsistence and recreational uses.

4. Effective spill contingency planning would minimize the incidence of spills and reduce the magnitude of their impact on the living environment.

5. A highly co-operative effort on the part of industry and government is recommended as the best means of achieving effective spill mitigation measures for a pipeline project.

MR. BAYLY: Thank you, Mr. Pettigrew. Mr. Commissioner, I wonder if this might be an appropriate time to break for coffee?

THE COMMISSIONER: Yes, certainly.

(PROCEEDINGS ADJOURNED AT 3:15 P.M.)

(PROCEEDINGS RESUMED AT 3:30 P.M.)

THE COMMISSIONER: Well, let's come to order.

MR. BAYLY: Mr. Snow is to repeat some remarks of Groucho Marx.

WITNESS SNOW: I will start out by outlining my involvement with the Mackenzie Valley Pipeline project. The Freshwater Institute of the Fisheries Research Board of Canada initiated a study of the impact of gas and oil pipelines, highway construction and operation on the freshwater ecosystems of the Mackenzie and Porcupine River watersheds in 1971, and this was carried out under the auspices of the Environmental Social Program, Northern Pipelines. Our headquarters was in Winnipeg with a field logistics base in Yellowknife, and field camps originally located in Fort Simpson, Norman Wells, Arctic Red River, Inuvik and Old Crow in the Yukon. Budgetary restrictions necessitated closing down the Norman Wells and Arctic Red River camps in '72. The remaining camps were operable until the end of the program in '74.

My affiliation with the project began in 1971, at which time I was a research scientist in charge of the Inuvik field camp. In 1973 the Old Crow field camp became included in this operation and therefore came under my jurisdiction. Until the end of the project I was involved in carrying out the oil spill impact evaluation side of our work, gathering baseline ecological data for the delta and the nearshore Beaufort Sea area, and writing reports and papers on these and

related subjects.

The scope of this study; our first activity was to conduct a general survey of the distribution and abundance of aquatic organisms in a vast and biologically poorly known region. Attention was focused upon benthic organisms because of their fundamental importance with respect to food chain inter-relationships and their utilization by indigenous fish species. Moreover, because of their relatively sedentary existence, they are well suited to act as biological indicators of technological disturbance to their habitat. Selected physical and chemical parameters that controlled their distribution, growth and abundance also formed an integral part of this study.

Following this general survey, an experimental approach was adopted to study the specific effects of two major types of disturbance to aquatic habitat occasioned by pipeline development. These were the effects of increases in suspended sediment from erosion and the effects of oil in water.

The suspended sediment studies were carried out primarily in the Fort Simpson area, whilst the oil spill studies were primarily undertaken in the Inuvik region. Data obtained from the whole area were, however, used to support the experimental studies with sampling stations located throughout the Mackenzie and Porcupine systems.

The objectives of our oil spill studies, briefly these were:

(1) To study changes in the structure of benthic

communities in selected lakes and rivers of the Mackenzie and Porcupine watersheds in response to the addition of northern crude oil. The one that we selected was Norman Wells crude for its ease of attainment.

(2) To study changes in water quality associated with the addition of Norman Wells crude to the selected aquatic ecosystems in the study areas.

(3) To study the fate of crude oil following experimental spills on the Mackenzie Delta lakes.

(4) To study the effect of Norman Wells crude on the colonization of river bed substrates by benthic organisms, and

(5) To make recommendations concerning contingency plans for spills of oil and other hazardous substances.

Some of the problems of oil pollution, and I'd like to make some general points concerning spills.

(1) First of all, the term "oil spill" is a generic term which covers all types of petrochemicals that may be spilled from refined gasolines and kerosenes through to crude oil. It's the latter type of spill that conjures up most people's images of a disaster, a great black or brown mess contaminating miles of rocky coastline and sandy beaches and causing death to thousands of sea birds. The visual impact of such an event is enormous. It gives rise to much the same emotion as would be expressed if one first visits a forest fire immediately after the fire has swept through it, the common response being, "My God, how will it ever recover?"

Yet we know from experience that forest fire burn areas do in fact recover, within varying lengths of time according to their latitude and are in fact an inherent part of natural change of such ecosystems. Much the same occurs in the recovery of an area that's been contaminated by an oil spill. There are many incidents of major oil spills that have occurred in more temperate latitudes such as the "Torrey Canyon" incident off the coast of the U.K., the "Arrow" in Chedabucto Bay off the eastern seabord of this country, and the Santa Barbara oil spill off the west coast of the U.S.A. All of these disasters had their impact on the marine environment but it was not an irreversible one. In all three cases mentioned there has, in fact, been a recovery of many of the affected segments of biota.

I do not wish to imply by these remarks that oil spills do not cause any damage or their effects may not be long-lasting. I do hold out the candle of hope that there will be recovery, and by "recovery" I do not necessarily mean a reversion to the former state before the oil spill. Ecosystems have ability and resilience at any latitude and providing certain limits are not exceeded, they will usually recover to restore a new balance of nature. Whether this new balance is acceptable to man or other components of the ecosystem is not always readily accessible.

Another feature of the visual impact of an oil spill is the conspicuous or highly visible components of ecosystems such as sea birds which are readily seen to be adversely affected by oil. Birds

are vertebrates, that is animals with backbones, and vertebrates only make up 5% of the animal kingdom. The other 95 is composed of animals without backbone, which are generally much smaller, occur in far denser populations, many of which are microscopic. But such microscopic components of ecosystems, both animals and plants, which form the basis of the food chains in the Beaufort Sea or the delta aquatic ecosystems as anywhere else. Such components may be just as adversely affected by the presence of oil as sea birds, even though this is not very often readily apparent.

The implications of such an effect in terms of the total integrity and stability of an ecosystem are far-reaching. This has special significance in terms of the Mackenzie Delta ecosystem because of the position that this area occupies in Northern Canada. It's very different from most other areas of the world, which have been subjected to oil spills. Most of the classic Maritime oil spill disasters have contaminated large areas of predominantly rocky coastlines. These coastlines are usually associated with a high degree of wave and surf action. Rocks that become contaminated with crude oil have thus usually subjected to strong tidal and wave action which would tend to cleanse them. They are also exposed to the natural cleansing activity brought about by indigenous organisms such as snails and limpets. These animals scrape the oil from the rocks and thereby assist in the cleanup process in temperate latitudes; but they do not occur along the coastline of the Beaufort Sea.

To date there have been no major oil spill disasters that have contaminated large areas of relatively quiet water with extensive mud flat zones. Such a situation clearly exists in the Mackenzie Delta and the nearshore Beaufort Sea area, including the Tuk Peninsula. Here we have an area where there are deltaic processes going on, creating large areas of sedimentary habitat.

These sediments are composed of basically very fine particles, silts, which are very readily admixed with oil. In addition to this, the self-cleaning ability of the area is severely restricted compared to a rocky shore. The mean tidal amplitude is approximately one or two feet. Wave and surf action is also far less than that normally experienced on more temperate rocky shores.

As a general rule of thumb, the smaller the particle size of sediment, the greater is its potential for contamination with oil. There are several documented cases where sandy beaches have been contaminated with oil from a spill, often to a depth of several feet.

As I stated earlier , there has been no major oil spill in a tidal mud flat area which by and large supports a more abundant and diverse community in which to compare effects. However, the potential for the absorption and holding of oil following a spill is potentially far greater in such an area than it is in a sandy area, and obviously more so than for a rocky area. It would therefore seem that the Mackenzie

Delta and its immediately adjacent offshore area represents a set of conditions which would tend to maximize the adverse effects of an oil spill were one to occur there.

The present level of hydrocarbon exploration activity in that area certainly increases the probability of an oil spill event. The delta is the focal point of gas and oil development activity in the Western Arctic. The main concern which therefore faces this productive area is one of cumulative impact. Not only do we have the possibility of major crossings of delta channels by the trunk gas line itself, but there is also the additional consideration of the gas processing plant, offshore drilling activity, and in the future an oil transportation system, probably a pipeline.

Each of these activities has associated with it the potential for spills of fuels of various kinds, and crude oil itself. These range from the minor incidents involving only a few gallons or a few hundred gallons of diesel or aviation fuel, up to the many thousands of barrels of crude oil which would occur in the event of an uncontrolled well head blowout during offshore drilling or an oil pipeline rupture.

The time of year at which any spill event occurred in the delta is of prime importance in determining the magnitude of the impact. No time of the year would be a good time to have an oil or fuel spill in the delta. The time at which one could best be dealt with would be the winter if the spill occurred on the surface of the ice. If it occurred under the ice,

then not only would it be very difficult to map the course of the spilled material, but the recovery of fuel would also be difficult to achieve. The worst time would probably be just following spring breakup when the Mackenzie is at peak discharge, most of the delta is flooded, and there is still some ice about.

Ice can have useful and impeding effects in terms of oil spill cleanup and containment. In some cases ice can act as a very efficient natural barrier in assisting ponding the oil, thereby facilitating its subsequent removal. If the ice is on themove, however, this would hamper the deployment of cleanup equipment and procedures.

Following spring breakup a spill of any kind of petrochemical would be distributed rapidly by the channels of the delta which would act as arteries allowing maximum disperal within the shortest possible time. It would also affect most of the delta lakes in its path which are normally flooded at that time. Later on in the season many of these same lakes would be immune from contamination by oil in this way.

A few comments on the effects of oil. Having outlined the broad area of concern, the susceptibility of the delta area to petrochemical pollution, I would like to briefly summarize the salient features of the effects of crude oil and petroleum products. Sea birds are probably the most obvious casualties of oil spills. Mortality usually results from the destruction of the waterproofing and heat insulation ability of their feathers, and also from

oil ingestion during preening. The delta and offshore areas are utilized extensively by many bird species, as I'm sure you've heard before now.

Apart from the direct mortality from oil spills is the additional long-term component which results from the loss of nestlings, the nest sites themselves being rendered useless for future generations by oil contamination, and the threat of degrading feeding, brood-rearing and staging areas.

Within the aquatic environment the more mobile organisms, such as fish, can and often do avoid contamination by oil. This may not always be possible in shallow areas in small lakes, or in coastal embayments. The delta has many examples of these three types of habitat, and the special significance here is the fact that the latter two habitats -- that is small lakes and coastal embayments -- are known to be feeding and nursery areas for juveniles and fry of several fish species. Fry in particular are especially susceptible to oil contamination, since they usually inhabit the upper water layers. The toxic aromatic lighter fractions of fish -- the lighter fractions of fresh crude oil can kill fish directly. Other longer-term effects include the formation of gill lesions and certain forms of skin cancer.

Beluga whales are annual visitors to the delta area, an important resource for the local people. These mammals also have the potential to avoid oil contamination, but they utilize the ice leads extensively in early spring. Süch leads would be

natural ponding areas for any oil pollutant. Although nothing is known of the effect of -- specifically of the effect of petroleum products on beluga, enzymology studies currently being carried out by Dr. J. Geraci at the University of Guelph indicate that their skin may be the major osmoregulatory organ of these animals and is obviously highly susceptible to any adverse effects resulting from contact with oil.

Perhaps I should explain, osmoregulatory organ is salt and water balance, a role that is usually carried out by the kidneys.

THE COMMISSIONER: Salt and water balance, did you say?

A Yes. But there is evidence that in the beluga the skin at least takes over part, if not all of this function.

Aquatic invertebrates show a spectrum of sensitivity to oil. Some species suffer massive mortality, for example, freshwater zooplanktonic crustaceans and marine anthropods, a shrimp-like crustacean, whilst others are relatively tolerant; zooplankton in delta lakes and anthropods in the nearshore Beaufort Sea are very abundant, and are extensively utilized as food by fish and marine mammals in the area.

My own work concerning the effects of relatively small quantities of crude oil in the Mackenzie Delta lakes indicated a subtle re-arrangement of benthic communities and produced an ecological shift. Certain organisms were completely wiped out to be replaced by others which were relatively rare prior

to the spill. After three years, a new balance has been established but the faunal assemblages are quite different from those occurring before the spill.

We determined that the most toxic fractions of two types of oil, of the crude oil that we used, disappeared very soon after the spill, and approximately half the oil evaporated after two days, leaving the heavier tarry residues. From our research studies we hypothesized three phases of oil effects on the delta lakes.

The first is characterized by acute toxicity, and lasts a matter of days. This overlaps with and is followed by a period of physical entanglement or smothering, which lasts a few weeks. Finally there may be prolonged chronic effects similar to eutrophication.

This phenomenon is not usually welcomed by society since it results in the proliferation of 'nuisance' algae and 'trash' fish at the expense of more desirable life forms. Ecologically the system has become impoverished. Diversity of the system has decreased and the natural balance has been destroyed. The implications of this could be far-reaching, depending on the size of the area affected.

With respect to the delta, I'd like to point out that I consider the lakes, clear ones in particular, to be oases of productivity that support not only the aquatic communities which I've been looking at, but are integral components of a much larger system encompassing local important species such

as the muskrat and waterfowl, all of which interact to produce the typical delta ecosystems that exist today.

I have some general concerns. So far I concentrated upon the delta area, its susceptibility to petrochemical pollution and potential impact. This does not mean that spill problems may not occur or that they are of lesser importance elsewhere in the Mackenzie Valley. Until an oil pipeline down the Mackenzie Valley is a reality, I consider the main threat to aquatic systems above the delta polluted by pipeline petrochemicals to be fuel spills from one-man storage sites or during transfer by pumps or trucks, and spills of pipeline test fluid (methanol) either during the testing process or during the transfer or storage.

Spills of even small to moderate quantities of fuel into any of the relatively productive clear-flowing eastern draining tributaries of the Mackenzie to be crossed by the gas pipeline are likely to cause impoverishment to the downstream areas similar to that seen in an oil spill experiment we carried on in Caribou Bar Creek. In this experiment, a small quantity of crude oil caused a reduction in benthic organisms of one-third their pre-spill abundance. Successive spillages or heavier contamination may produce an even greater decrease, thereby seriously affecting the suitability of that stream for fish utilization and impairing its overwintering capacity, or destroying its spawning potential.

Our experimental section of Caribou Bar Creek recovered almost completely one year

following the spill, but it may not be safe to extrapolate this effect to any system, particularly where there is a greater potential for substrate contamination than we had at Caribou Bar. However, by virtue of different sediment composition or large volumes of oil or fuel spilled, streams in more temperate latitudes which had been subjected to fuel spills have not recovered over a period of four years.

The north has a history of fuel spills in the thousands of gallons category, most of which have been attributed to human error or equipment malfunction. I have read articles concerning the delta environmental protection unit contingency measures and equipment, but I've never seen a comprehensive D.E.P.U. contingency plan for the delta itself. Containment booms and slick-lickers appear to be heavily relied upon in the CAGSL application in the delta as a whole.

My main concern stems from the fact that to the best of my knowledge, containment booms are not effective in currents equalling or exceeding four feet per second, two to three knots, or with effective wave heights exceeding three feet. These conditions are equalled or exceeded throughout much of the Mackenzie system. Apart from the efficacy of such equipment, I have concerns regarding the rate of execution of contingency measures and training of personnel. These concerns can best be framed in the following questions. I would ask the applicant regarding his contingency plans:

(1) What measures are being taken to ensure that transfers of fuel and other hazardous chemicals will take

place with minimal risk of spillage?

(2) Have the containment and cleanup measures envisaged by the applicant been tested under the conditions which they're anticipated to be used?

(3) Does the applicant intend to test such procedures and equipment periodically? If so, how frequently, and does he intend to have practice drills to ensure that personnel are familiar with and proficient at executing such procedures?

(4) How does the applicant intend to anchor a boom in the Mackenzie River and what is the response time to deploy such equipment?

I feel that any contingency plan should at the very least cover these points. These comments and concerns are also applicable to the gas-gathering facilities, but they assume more importance in this respect since storage and fuel utilization at a specific location will probably be greater than at similar sites along the trunk gas line.

The size of the area potentially susceptible to spillage is also larger. This fact, together with the low topographic relief at two of the gas plant sites (that's Niglintgak and Taglu) coupled with their proximity to the Beaufort Sea also increase the potential ecological impact.

The gas producers are contributors to DEPU and appear to be using that unit as the main component of their contingency plans for spills in the delta area. The misgivings I have concerning the efficiency of booms are also pertinent in this context.

Because of the northerly location of two of the gas plants, the distance to the coastal areas where fuel-spill impact is likely to be greatest is very short. Time for the deployment of containment and cleanup equipment will likewise be very short. In the area of Richards Island, which I am now considering, the topographic relief is very low and any failure or delay in containing a fuel spill will expose the slick to storm surges. This would increase the probability of contaminating large areas of land and lakes as well as the coastal region with its sensitive avifauna and fish-rearing habitat.

An additional problem arises in this area. Should a spill get out of control and contaminate the coastline and inland areas resulting from storm surge activity, and this is one of on-land cleanup, because of the susceptibility of this particular terrain to vehicular disturbance no heavy cleanup equipment could be used there, and cleanup could only be effective by using a large amount of manpower. I have not seen this problem really taken into account in any contingency plan.

Such concerns are relevant when considering fuel spills originating at two of the gas plant sites, but a new dimension is added when considering effects on the same area resulting from uncontained well head blowouts during offshore drilling for oil. This is the substance of the Preliminary Environmental Assessment - Offshore Drilling for Oil in The Beaufort Sea, which is an exhibit at the Inquiry, and

I do not propose, therefore, to go into this issue in detail as it's already been dealt with by Dr. Al Milne.

I would, however, like to summarize the main points, and add a concern of my own which I don't feel is addressed in that document.

Firstly, by virtue of the possibility of large volumes of crude oil being released over a long period of time, and also by virtue of the locations of the proposed drill sites, the possibility exists of far more extensive coastal and delta contamination than would be the case with fuel spills from either the gas plant locations or trunk gas pipeline sites.

Secondly, a spill from either of the proposed drill sites has a potential to contaminate the first major lead which opens up annually offshore from the delta. This is a very important zone with respect to migratory birds, beluga whales and seals in the spring, and the potential for impact is great. The major concern with respect to contingency planning is that we are largely in the realm of untried technology. Any of the conventional containment and cleanup devices currently used at offshore locations elsewhere have not been proven to operate under ice-infested conditions such as those obtaining in the Beaufort Sea. Some work carried out under the auspices of the Beaufort Sea project, indicate that under certain conditions oil in the ice-covered areas can be burned off. There is no doubt that fresh crude will burn even in Arctic conditions, but weathered oil is another proposition. It should be pointed out that attempts to remove "Torrey

Canyon" oil at sea by burning were a failure, even with the application of thousands of gallons of gasoline and napalm. It's also impossible to ignite emulsified oil and this brings me to the concern not really addressed in the Beaufort Sea assessment.

A well head blowout is accompanied by large volumes of gas. The possibility therefore exists that there may be extensive emulsification of released oil. This would pose two problems:
(1) it would disperse the oil over a wider area, and
(2) it would destroy the ability to remove such oil by burning, which is the most effective cleanup procedure currently available.

Clearly there is a need for speeding up of the research and development aspects of oil spill containment in offshore areas. Devices which are promised for Arctic operations are surface curtains to contain -- to confine oil and gas from a blowout to a drill site and possibly some form of underwater containment such as a dome on the sea bed.

MR. BAYLY: Q Dr. Snow, perhaps you could explain the phrase "surface curtain" for the Commission.

A Oh, yes, these are one of the devices which was investigated in the Balaena Bay experiments. It is in fact a boom which is -- an anulus is cut into the ice around the drill site and a curtain is placed in suspended to three feet below the surface, and weighted at the bottom of the skirt, hopefully to contain any oil or gas to the area of the

drill site, should a blowout occur on the sea bed. Is that clear?

It's also clear that in the case of oil or fuel spills, the old adage:

"An ounce of prevention is worth a pound of cure,"

was never more true. The cost of cleanup following any of the major Maritime oil spill disasters was enormous, and the cost of compensating the local fishery alone following the "Mizushima" oil spill in Japan was $56 million. This is a personal communication from C.W. Nichol, "Canadian Observer" at that spill.

This latter incident also has implications in the current discussion of the delta impact. The "Mizushima" spill of some 10¼ million gallons of hot bunker-C occurred when a steel storage tank in a dyked enclosure ruptured. The dyke was breached and oil flowed towards the harbour. The contingency plan which was hitherto regarded as being adequate was immediately executed. This involved 30,000 meters of boom, 738 boats, 153 aircraft, a great deal of ancillary equipment, and 8,189 workers. The spill could not be successfully contained even by this massive operation. Furthermore, it occurred under nearly ideal conditions, i.e. manpower and equipment availability was no problem. The area was relatively calm compared to the Beaufort Sea and delta area. There are obviously grave implications should a similar event occur in the Canadian Arctic.

The adequacy of dyking procedures is relevant to discussion of this and similar problems.

It should go without saying that a dyked area should be impermeable to the fluids it must contain but I know of at least one fuel storage dyke in the north which was, and still is, constructed of completely porous material.

The applicant states that his dyked areas will be impermeable but details should be provided as to how the required degree of impermeability is to be achieved. The anticipated life span of such dyked areas, inspection procedures and maintenance programs. I now have concerns regarding pipeline testing.

It's my understanding that the applicant intends to use methanol as a freeze depressant in testing of all pipeline sections north of 60. The applicant states that test sections will be ten-mile spread chilled by 26% methanol solution. I believe this test spread size has now been reduced to three miles. The proposed method of disposal of the 1% solution doesn't, in my opinion, pose a major threat to the integrity of aquatic ecosystems. But this is not the case with the 26% solution. The applicant has no specific contingency plan to deal with the possibility of all the methanol contained in a test spread somewhat in excess of a million gallons, being released during a test. Methanol solutions of only a few % have been shown by the applicant to pose a threat to Arctic fish and their eggs. The greatest impact of a methanol spill during a test would occur if all the fluid entered low discharge clear river, such as most of the eastern tributaries of the Mackenzie, which have flow under ice

during the winter.

I have estimated that if this were to occur, say in the Martin River,at its lowest winter discharge, which is approximately five cubic feet per second, the methanol -- this would be equivalent to methanol replacing the normal water flow for 11 hours over a distance of two-thirds of a mile. Assuming dilution of the methanol to 4%, once it got into the river, these two figures would be increased by a factor of six. A 4% solution will adversely affect fish eggs and probably also most of the benthic invertebrates contained in the affected section of the river.

By contrast, if the spill event occurred at the proposed East Channel crossing site, the impact would be negligible, owing to the relatively high discharge even during winter, approximately 26,500 cubic feet per second. The corresponding figures for this crossing would be seven seconds in .7 feet. The dilution effect is readily apparent.

Lakes present a different set of problems, since their water is static on the winter ice, and dilution of introduced methanol would be a very slow process. Assuming a small lake similar to those close to the pipeline route with a volume of 12 million gallons, the introduction of a 26% methanol from a three-mile spread would ultimately result in a 5% solution in the lake, and this is cause for concern. Larger lakes affected in this way would be expected to have lesser impacts in relation to their larger volume.

I would like to emphasize that

these estimates are based on assumptions and probably at best give the problem an order of magnitude. It would assist the assessment of impact if the applicant were to give detailed information concerning the actual test procedure itself, particularly at water bodies.

Finally I have a set of recommendations. To alleviate the major concerns I've outlined, I propose the following recommendations:

(1) High priority should be given to the early detection of spill incidents and to the training of conscientious operators and supervisory personnel.

(2) High priority should be given to dyked area design, construction and inspection.

(3) Oil spill containment and cleanup technology research and development should be accelerated.

(4) Adequate environmental monitoring programs should be set up to follow all aspects of pipeline construction, operation and maintenance. These would probably best be carried out by joint industry, federal agencies.

(5) Federal regulatory and enforcement agencies should ensure that there are adequate personnel to deal with a development of the nature and magnitude as that proposed.

(6) In the absence of an adequate contingency plan to deal with methanol spillage during pipeline testing, the applicant should reconsider the use of heated water as a test fluid with its subsequent return to natural water courses after treatment, cooling and aeration.

MR. BAYLY: Mr. Commissioner, this panel is now available for cross-examination and I don't know if you want that to begin this afternoon or on

Monday.

MR. GOUDGE: I think it would be more expeditious for a number of reasons if we broke now and commenced Monday with the cross-examination.

THE COMMISSIONER: Right. Well I think we should begin at 9:30 Monday, returning to our usual hours of sitting and would you, Mr. Goudge, make sure that Dr. Milne is asked, when he returns to the stand, to comment on Dr. Snow's observations on the consequences of the emulsification of oil and the matters he said regarding the impact that would have on disperal of the oil and on something else. It must be time to adjourn.

What was the other thing?

A Ignitability.

THE COMMISSIONER: Yes, ignitability, of course, because thatwas an important part of Dr. Milne's presentation. Don't forget to bring that up when he returns to the stand.

All right, we'll adjourn till 9:30 Monday morning, and the community hearing will be two o'clock tomorrow afternoon at the Ingamo Hall. So thank you, Mr. Pettigrew, Dr. Snow, Mr. Logan.

MR. MARSHALL: Mr. Commissioner, I wonder if counsel should have a word about our schedule for next week so we can --

THE COMMISSIONER: Certainly.

MR. GOUDGE: Perhaps we could take five minutes after we adjourn.

THE COMMISSIONER: Yes, fine.

(REPORT ON SHALLOW SEISMIC SURVEY IN 3 AREAS OF MACKENZIE DELTA, 1975, MARKED EXHIBIT 469)

(QUALIFICATIONS & EVIDENCE OF R.K. PETTIGREW MARKED EXHIBIT 470)

(QUALIFICATIONS & EVIDENCE OF N. SNOW MARKED EXHIBIT 471)

(QUALIFICATIONS & EVIDENCE OF W.J. LOGAN MARKED EXHIBIT 472)

(PROCEEDINGS ADJOURNED TO FEBRUARY 16, 1976)